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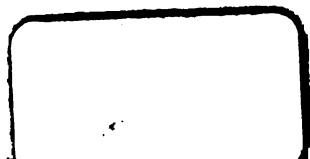
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PRACTICAL HANDBOOK

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ON

PUMP CONSTRUCTION.

BY

PHILIP R. BJÖRLING.

WITH NINE PLATES.



E. & F. N. SPON, 125, STRAND, LONDON.

NEW YORK: 35, MURRAY STREET.

1887.

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THIS LITTLE BOOK

IS

WITH KIND PERMISSION

Dedicated

TO

HENRY DAVEY, ESQ., M.I.C.E., M.I.M.E., Etc., Etc.,

OF LEEDS,

AS A SLIGHT TOKEN OF ESTEEM,

BY

THE AUTHOR

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PREFACE.

"WHERE can I obtain a Practical book on Pumps?" This oft-repeated query addressed to me by numerous gentlemen with whom I have become acquainted in the execution of my professional duties in this special line, has induced me to offer what varied and extensive experience has taught me to be the main basis upon which Pumps, such as herein described, should be constructed. Being unable myself to obtain the particulars required in cases of this description in book form, it is with a hope that a lucid and graphic description of those main points which form a safe and effective guide for the construction of first-class Pumps, will prevent the production of those abortive pieces of machinery, designated by courtesy, Pumps, that the notes of some sixteen years have been condensed into what I hope will prove to be a handy book for reference or consultation.

It is also hoped that this small manual will find a welcome at the hands of those who have the practical part to perform, as well as those who either undertake or superintend the designing.

I have to thank Henry Davey, Esq., for kindly looking over and correcting the matter, and any alteration that may be deemed at all beneficial to the readers, will be gladly accepted and considered, with a view to future editions.

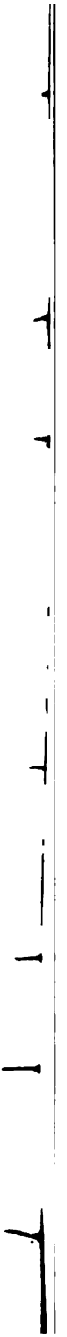
P. R. B.

MUCH WENLOCK, SALOP, 1886.



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PRACTICAL HANDBOOK

ERRATA.

Page 4, line 19, *for* "Plate VII." *read* "VIII"

" 11, " 23, *for* "Figs. 11, 12, and 13" *read* "10, 11, and 12."

" 12, " 21, *for* "Figs. 14 and 15" *read* "13 and 14."

" 13, " 24, *for* "of the annular space" *read* "to the annular space."

" 19, " 20, *for* "a cork" *read* "a cock."

" 35, " 3 *from bottom, for* "to tighten the ball" *read* "to lighten the ball."

Plate 1., consists of a barrel, bored perfectly true and parallel, into which fits a bucket. This bucket is fitted with a valve which opens upwards; a valve is also fitted at the bottom of the barrel, which also opens upwards. This latter valve is called the suction-valve, or perhaps, more commonly, the sucker.

The action is as follows:—When the bucket is raised in the barrel by means of the handle, a partial vacuum is formed under it, more or less complete according to the perfection of the working parts and tightness of the joints in the suction-pipe. The valve in the bucket is kept shut by the pressure of the air above it, while the suction-valve will be forced upwards by the water rising into the barrel, which water is forced into the space otherwise forming a vacuum under the bucket by the air pressing on the exposed surface of the water in the well; in other words, by abstracting the pressure of the air from off part of the surface of the water, that portion

under the bucket is forced upwards by the pressure on the remaining portion of its surface. Supposing the up-stroke of the bucket completed, and the space under the bucket is filled with water; on commencing the down-stroke the water cannot return through the suction-valve, for it will shut immediately by the weight of the water, but the bucket-valve will open by the same effort. Thus the water will be forced from the under side to the top side of the bucket. It can be easily understood that the water above the bucket can be raised to any height required; but the height to which the water under the bucket can be raised above the natural level of the water in the well is limited by the law of nature within the range of 30 to 33 feet; that is, if the vacuum could be obtained perfect, there could not be more than 30 to 33 feet from the surface of the water in the well to the under side of the bucket, when it is at the top of its stroke. A comparison of the relative weights of water and air would appear to warrant us placing the suction-valve of a pump at a greater height above the surface of the water in the well or pit than is usually adopted in practice, but the imperfections of the different parts of the pump do not admit of it being carried beyond from 20 to 25 feet; the author, however, prefers two pipes, each 9 feet long, or 18 feet.

CLASSIFICATION OF PUMPS.

The pumps mentioned in this little treatise may first be divided broadly into Vertical and Horizontal.

Vertical Pumps are again divided into :

1. Ordinary Suction Pumps or Bucket Pumps.
2. Suction and Lift Pumps.
3. Plunger Pumps or Force Pumps.
4. Bucket and Plunger Pumps.
5. Piston and Plunger Pumps. ✓

Horizontal Pumps are divided into :

1. Double-acting Piston Pumps.
2. Single-acting Plunger Pumps. ✓
3. Double-acting Plunger Pumps.
4. Bucket and Plunger Pumps.
5. Piston and Plunger Pumps.

DESCRIPTION OF PUMPS.

VERTICAL.

Ordinary Bucket Pump. ✓

Fig. 1, Plate I., illustrates an ordinary *hand-pump* actuated by a lever: A is the barrel; B the bucket fitted with an ordinary leather clack-valve; C is the suction-valve; D the suction-pipe; E delivery spout; F the lever or pump-handle; G fulcrum; and H the bucket-rod. The bucket enlarged is shown in Figs. 39 and 40, Plate VII., and the valve in Figs. 17 and 18, Plate V.

Vertical Bucket Pump used in Mines.

This pump is illustrated in Fig. 2, Plate I., in which A represents the pump "trees" or rising main; B the working barrel; C the "drop clack-piece"; D the clack-piece proper; E the suction-pipe or windbore, fitted with a strainer F; in this case the windbore is of the sliding type used for sinking purposes. The bucket usually adopted for this class of pump is shown enlarged in Figs. 41 and 42, Plate VII., and the clack in Figs. 20, 21, and 22, Plate V.

The "pump trees" for the bucket pumps should always be made about one inch larger in diameter than the working barrels in order to obviate the friction which would occur when the buckets have to be lowered or drawn, supposing the latter were made the same diameter. The pump trees are usually made of 9-foot lengths of pipe, with a few matching or making-up pieces 6 feet

and 3 feet long for convenience of fixing. They are generally flanged, but sometimes made with spigot and faucet joints. The joints are commonly made by lead or wrought-iron rings wrapped round with old flannel or common woollen cloth soaked in tar, and when screwed up makes a perfect water-tight joint, and can be separated and remade with great facility. For heavy pressures, however, there is no joint as good as the guttapercha cord joint.

If the water which the bucket pump has to lift is highly charged with acid, the rising main is frequently made much larger in diameter and lined with staves of wood fitted with great care, otherwise the cast-iron pipes will soon be eaten away by the corrosive action of the acid. The staves are put round the interior of the pipe, a narrow space being left between the first and the last stave; into this space are driven two wedge-shaped pieces, one driven in from each end of the pipe.

The working barrel is usually made of cast iron, but when the water to be lifted is contaminated with acids, it should be made of solid gun-metal; but as this is too expensive for large pumps, it is made of cast iron lined with brass or gun-metal, and where the water is very bad phosphor-bronze is used. It must be bored perfectly true and parallel, so that the bucket can work up and down with ease and with as little friction as possible; it must be bell-mouthed or trumpet-shaped at the top, to allow the bucket to enter easily without injuring the bucket leather when lowered down.

Sometimes a door is provided above the working barrel for access to the bucket, so as to prevent having to draw the bucket out at the top of the pit.

The clack-piece is also provided with a door for access to the suction-clack. Between this clack-piece and the

working barrel is sometimes introduced another piece, into which is dropped an auxiliary fixed clack, in case something should happen to the proper clack, and the clack-door should be under the level of the water in the mine. The seat in this clack-piece is a little less than the bore of the working barrel and bored slightly taper, so that it can be drawn from the top.

The ordinary windbore consists of a pipe, furnished at the bottom with an enlargement perforated by holes, which prevents any large pieces of foreign matter from entering the pump and getting into and hanging the valves. This bottom part is either egg-ended, as shown in Fig. 2, Plate I., flat-bottomed or round, and for very small pumps the suction-pipe is frequently plugged up at the bottom and holes drilled in it. The aggregate area of the holes in the windbore should be at least one and one-half times the area of the suction-pipe; for sewage purposes they ought to be not less than twice the area.

The sliding windbore illustrated in Fig. 2, Plate I., is made of cast or wrought iron, the latter preferably, although it is more expensive, on account of its lightness. It is used for sinking purposes. It consists of a cast-iron pipe bolted to the suction branch of the clack-piece. This pipe is turned perfectly true and parallel to work freely in the stuffing-box and gland, which are bolted to the outer sliding pipe, the gland and stuffing-box being bored true to fit the pipe. If this pipe is of cast iron the strainer is usually cast in one with it, but if of wrought iron it finishes with an L iron ring, to which a loose strainer is bolted or riveted. The fixed pipe is made 10 feet long, to allow the sliding pipe to lower 9 feet, and when the sinking has proceeded thus far a 9-foot length of suction-pipe is inserted, then the windbore is again allowed to sink 9 feet, and so on until the suction has reached its

limit, when the suction-pipe is removed, the pump lowered, and the previous process repeated. The strainer for sinking purposes is usually egg-ended or heart-shaped.

Vertical Plunger Pump.

A *small vertical plunger pump*, such as is used for boiler feeding and for purposes where a small quantity of liquid has to be raised, is illustrated in Figs. 7 and 8, Plate II. Fig. 7 is a sectional elevation and Fig. 8 is a plan. The construction is so very simple that the illustrations will explain themselves. A great error which often is overlooked in these pumps is that the designer, for the sake of uniformity in the appearance, places the centre of the suction and delivery branches in one line, and thereby forms an air-lodge, which is a great detriment to the quantity of liquid raised.

It will be seen in Fig. 7 that the suction branch is low down and the passage from the same to the barrel is at the top of the latter, and that the passage from the barrel to the delivery valve is also at the top, leaving no place whatever where any air can be kept, for it always rises to the highest point. The valves and seats are not shown in the illustration, because they alter in design for different liquids and pressures against which the pumps have to work.

Vertical Plunger Pumps used in Mines.

This pump is shown in Fig. 3, Plate I. It consists of a pole-case or plunger barrel, fitted at the top with a stuffing-box and gland bored accurately to fit the plunger. The case is made, according to the diameter of the plunger and the length of the stroke, from one to two inches larger internal diameter than the plunger.

The plungers are sometimes made of cast iron fitted with a centre bolt; sometimes a boss is formed at the top of the plunger, into which the pump-rod is cottered; in small pumps the rod is in many cases screwed into the boss and secured by a back nut. In very small pumps the plunger and rod are made in one forging. The best plan is to carry the rod through the plunger and secure it by means of a nut and split cotter.

In Cornwall the plungers mostly consist of wood spears or rods covered with cast-iron casing, turned perfectly true and parallel, and secured to the rod by means of wood wedges. This plunger is shown in Fig. 3, Plate I.

The plunger-case is bolted to the top flange of one branch of the double pipe or H-piece, and to the bottom flange below is secured a pipe of the same diameter as the plunger-case, this pipe being blocked up at the bottom and provided with a foot; this pipe is also useful for collecting the sediment; a blow-off cock should be provided at the bottom, so that the sediment can be blown out at intervals when necessary. The other pipe of the H-piece is fitted with the suction-clack and a door for easy access to the same.

The suction-pipe or windbore is bolted to the flange below the suction or bottom clack.

To the top of the same branch of the H-piece is secured the rising main or pump "trees."

There is one objection to this design of plunger pump, namely, that the delivery clack is placed below, leaving a space above it round the plunger for air, and to allow this air to escape the packing in the stuffing-box must be left slack enough to allow the air to pass through it. The delivery clack ought to be placed just below the stuffing-box, and the internal diameter of the pole-case should be twice the area of the plunger. There should be a cup

formed round the top of the plunger gland for water to prevent the air passing through the gland and stuffing-box into the pole-case on the up-stroke of the plunger.

The action of the plunger pump is as follows:—On the up-stroke of the plunger the water enters from the sump or tank by the windbore (which in this case is flat bottomed, and not sliding, as shown in Fig. 2, Plate I.), passes through the suction-clack, the double-pipe or H-piece, into the space left under the plunger; and on the down-stroke the water is forced through the delivery pipe, up the rising main, and delivered at the top of the same, either into a tank, from which the next set gets its water, or into a collar launder or spout at the top of the pit mouth.

The Hollow Plunger Pump.

The hollow plunger pump is a combination of the bucket pump and the plunger pump. It is illustrated in Figs. 4, 5, and 6, Plate I. Fig. 4 is a sectional elevation, Fig. 5 an enlarged view of the top of the plunger, and Fig. 6 the plan of the delivery valve. The plunger-case is similar to the ordinary one, and fitted at the top with a stuffing-box and gland; to the top of the stuffing-box is secured a delivery clack-piece furnished with a door for access to the delivery valve, and to the top of this clack-piece is bolted a cover provided with a stuffing-box and gland for the pump-rod (not shown in the illustration).

The plunger consists of a hollow pipe without flanges, turned all over perfectly true and parallel; it is furnished at top and bottom in the inside with two lugs, through which pass two wrought-iron rods provided at the bottom with double nuts, and at the top secured to a cross-head forged on the main pump-rod and secured by double nuts.

The delivery valve, in this example of hollow ram

It will be seen in the cross-section, Fig. 12, Plate III., that there are no places where the air can lodge, and that any air contained in the water must enter into the air-vessel, and there replenish the air which has been absorbed by the water and passed away from it.

Single-acting Plunger Pump.

The single-acting plunger pump is illustrated in Fig. 15, Plate IV. This pump is undoubtedly the best plunger pump. It consists of a cast-iron working barrel; on the top of one end is a branch fitted with a delivery valve box. The suction-valve box is cast in one with the back cover of the barrel. Both the suction and delivery valve boxes are fitted with covers for easy access to the valves for repairs or renewal. The peculiar feature in this pump is that the centre line of the plunger is below the centre line of the working barrel, and the area of the barrel is twice that of the plunger. It will be seen also that the water is rising all the way during its passage through the pump, and that there are no air-lodges present at any part of it.

Double-acting Plunger Pump.

This pump is illustrated in Figs. 14 and 15, Plate IV. It consists of two working-barrels, which are firmly bolted to a strong bed-plate by means of well-ribbed feet. Each barrel is furnished with a delivery branch on the top, and a suction branch on the side, the top of the latter branch should be placed level with the top of the working-barrel to prevent air-lodge. One of the barrels is provided with a stuffing-box and gland for the pump-rod at one end, and a gland and stuffing-box for the plunger at the other end. The other barrel is furnished with a stuffing-box and gland for the plunger at one end and a cover for the introduction of the plunger at the other. The plunger is turned perfectly true and parallel to work in the stuffing-

boxes and glands, which are bored to receive it. When bad water is raised, it is sometimes covered with brass, gun-metal, phosphor-bronze, or copper, and at other times made of solid gun-metal. All the valve-boxes are cast separate and bolted to their respective branches provided on the working-barrels. All the surfaces are round, to withstand heavy pressures. The valves are made of different material and are differently constructed according to circumstances.

Piston and Plunger Pump.

This class of pump is illustrated in Fig. 16, Plate IV. The principle of this pump is similar to the bucket and plunger pump described on page 10, and illustrated in Fig. 9, Plate II. It consists of a working-barrel in which works a piston. The rod is enlarged to form a plunger one-half the area of the piston.

The action of the pump is as follows:—Supposing that the piston is moving from left to right; then the suction-valve opens and allows the water to fill the working-barrel. As soon as the piston reverses its motion and travels from right to left the water is forced through the delivery valve; but as the plunger is only half the area of the piston, one-half of the water will pass through the top passage of the annular space round the plunger; the remaining half will pass into the delivery pipe. When the piston is again reversed, that is, travelling from left to right, the water that remained round the ram is delivered through the rising main. It will be seen that this, like the bucket and plunger pump, only sucks once in each revolution of the crank, or double stroke if the pump is direct-acting, but delivers twice; so that it is a double-acting delivery with only two valves, the quantity of water discharged being equal to a double-acting piston-pump having a piston of the same diameter as the ram.

REMARKS ON DESIGNING PUMPS.

The *space between the suction-valve and bucket, plunger, or piston*, as the case may be, should be as little as possible, consistent with ample waterway being given.

All *passages* should be as *straight* as possible, and when bends are necessary, the radius should be an easy one.

Sudden enlargements and contractions in the passages should be avoided, but if an alteration in size or shape of the passages is necessary, it should be made gradually.

Care should be taken that the *suction-pipe* should be the *lowest* point in the pump, and in no case must there be any part of the suction portion of the pump above the top of the barrel, and the delivery passages should be above the top of the barrel, so that there is no place for air to lodge, as *air-lodges* affect the *efficiency* of the pump.

There must be *no* part of the *suction-pipe higher than the suction branch* on the pump.

If the pump is required to raise *hot water*, there should be very little suction; in fact, it is best, if possible, to have the water running into the pump.

Long suction-pipes should always be provided with a *foot-valve* just above the windbore or strainer, in the well or pit.

Great care must be exercised to have *equality of metal* all through the pump, and where a greater or less strength is required, the alteration from one to the other must be gradual.

All *corners* should be *well rounded*, with a radius greater than the thickness of the metal.

There should be as *few flat surfaces* as possible, and where there are any they should be well ribbed.

Joints in the *suction-pipes* and the *suction part of the pump* must be very *carefully* made, and *perfectly tight*, as great damage and annoyance is often caused in this way by badly made joints.

Change of direction in the *flow of the water* should be avoided as much as possible. After a current of water has received an impulse, it is necessary that the motion imparted should be continued with a uniform velocity throughout its whole course ; any change in that velocity will cause considerable loss in power by overcoming the inertia. The motion of a crank moving in a circle with uniform speed is therefore an imperfect machine for moving a pump-piston, because the motion which it imparts changes at every point of its course. The changes of a piston should be sudden, and its velocity uniform. If any irregularities in the motion of a pump-rod are advantageous, it is the reverse with the motion of a crank.

In *vertical pumps* the delivery valve box should always be at the *highest* part of the working-barrel.

MATERIALS OF WHICH PUMPS SHOULD BE MADE, AND THE CLASS OF PUMPS FOR DIFFERENT LIQUIDS.

For *strong acids*, single-acting plunger pumps made of earthenware, stoneware, glass, guttapercha, or cast iron lined with guttapercha.

Earthenware or *stoneware* pumps are of the plunger type, the plunger and the pipe-joints being made with asbestos. The packing gland and all the joints are either made by flanges, by collars much smaller in diameter and tightened by means of wrought-iron rings, bolts and nuts, or by spigot and socket, like ordinary stoneware piping. The plunger, valves, and seats are accurately ground together. When these pumps are used for forcing thick and viscid liquids, they should never make more than eighteen to twenty strokes per minute, but if used for thin acids, they can be driven at the usual speed for water pumps.

Glass Pumps.—These pumps are of the single-acting bucket type; the barrel is made of the best plate glass, bored and polished perfectly true and parallel; the top and bottom chambers are made of lead if strong acids are to be pumped. The chambers are furnished with lugs, and are held together by wrought-iron tie-bolts, with double nuts, one on each side of each lug. The top chambers are also provided with a flange for the delivery pipe, and the bottom chamber for the suction-pipe.

Sometimes the *acid* is raised by means of a *double-acting air-pump*. The acid eggs are filled with acid by gravita-

tion; when the egg is full, the delivery pipe of the pump is set in communication with it and the pump forces air into the same, and by that means elevates the acid to the tank or cistern without passing through the pump.

For *Weak Acids*, double-acting piston pumps, and plunger pumps; all parts made of gun-metal.

For *Ammoniacal Liquor*, any type of pump will do, but they must be made of cast iron. The same also applies to *Anthracene Oil*.

For *Beer*, bucket pumps are generally used, made of gun-metal throughout for small pumps, but if large, they are for cheapness made of cast iron with gun-metal or gun-metal lined barrels.

For *Benzole*, double-acting piston pumps made of cast iron, working-barrels lined with brass, or if the pumps are very small, wholly of gun-metal.

For *Benzoline*, double-acting piston pumps, or single, double or treble-barrel bucket pumps, made of cast iron with gun-metal or gun-metal lined working-barrel or barrels.

For *Bleaching Mills*, double-acting piston pumps, or treble-barrel bucket pumps, of cast iron, with the barrel or barrels of gun-metal or lined with gun-metal.

For *Bore-holes*. These pumps are of the single-acting bucket type, and consist of a wrought-iron suction pipe the upper part of which is screwed into the bottom of a gun-metal, or cast-iron gun-metal-lined working-barrel, the top being screwed into a wrought-iron delivery pipe or rising main, through which the pump-rods pass. The joints in the suction-pipe and rising main are flush both inside and out. The lengths of pump-rods are the same as the rising main, and coupled together either by brass sockets or screwed into one another. These pumps sometimes deliver the water at the top of the well; in other cases, when the water has to be forced above that

point, a delivery chamber must be bolted on the top of the rising main, and this chamber be provided with a cover furnished with a gland and stuffing-box, and a flange for receiving the delivery pipe.

For *Breweries*, treble-barrel plunger pumps, treble-barrel bucket pumps, or horizontal double-acting piston pumps, with all the parts made of gun-metal.

For *Creosote*, double-acting piston pumps, or single, double, or treble-barrel bucket pumps, made entirely of cast iron.

For *Domestic purposes*, the ordinary bucket pump made of cast iron.

For *Drainage*, almost any class of pump, but the best is the double-acting piston pump or treble-barrel plunger pump, placed horizontally on a massive frame. All parts may be made of cast iron.

For *Dyeworks*, double-acting piston pumps; the material for their construction depends upon the chemical properties of the dyes to be raised.

For *Fire Engines*, the best type of pump is, without doubt, the bucket and plunger type; but for direct-acting steam pumps, the double-acting piston pump has done very good service, the best being made of gun-metal with copper air vessel, but pumps of cast iron with working-barrels lined with brass or gun-metal are very often used.

For *Gasworks*, double-acting piston pumps, double-acting plunger pumps, or piston and plunger pumps; all parts made of cast iron.

For *Gelatinous fluids*, double-acting piston pumps or piston and plunger pumps, made of gun-metal or cast iron lined with gun-metal.

For *Glutinous fluids not containing acids*, plunger pumps, single, double, or treble-barrel; they should be made of cast iron throughout.

For *Irrigation*, see Drainage, page 18.

For *Malt Liquor*, see Breweries, page 18.

For *Milk of Lime*, the double-acting piston pumps, or the double-acting plunger pumps are the best ; they should be made entirely of gun-metal, but on account of the great expense they are usually made of cast iron, the working-barrel being lined with brass or gun-metal.

For *Mines*, the large vertical bucket pumps, the plunger pumps, the horizontal double-acting piston pumps are used ; but the best are the *horizontal double-acting plunger pumps* for the following reasons :—

First. There is less friction in the ram working through a stuffing-box than in the bucket working against the inside of the pump barrel.

Second. When the water, as is generally the case in collieries and mines, is impregnated with sand, grit, mud, and other foreign matter, the wear and tear of the plunger is prevented by the space underneath it forming a receptacle for the solid matter, which is not the case in the piston pump. A ~~cock~~ ^{cork} should be provided on the under side of the barrels, so that the sand or sludge can be blown off at intervals, when necessary.

Third. The cost of repacking the ram is only nominal, but the cup-leathers for the pistons are a great expense.

Fourth. The ram being packed from the outside, leaks are immediately detected, and the glands can be tightened in a minute while the pump is running, and the stuffing-box repacked in a very short time, whereas in a piston pump a great leakage can be going on for a long time without being noticed, representing so much duty lost ; a great deal of time is also lost in putting in new cup-leathers, or taking off the worn piston or bucket and putting in a new one.

Lastly. That the ram can be lubricated, and the corroding action of acidulated water greatly reduced.

The *Bucket Pump* is very useful, and mostly employed for sinking or for the bottom lift in a mine, where there is any danger of a sudden inburst of water. The working-barrel should be made of very hard metal, and the length of the rods nicely adjusted, so that the leather of the bucket will come slightly above the bore in the up-stroke; if the water is clean and not contaminated with acid, and the lift not too great, then the bucket pump is probably the best. The occurrence of air getting into the pump does not cause the shock which is experienced with plunger pumps.

The *objections* to these pumps are, however, very great, namely:—

First. The rapid wear and tear of the leathers on the bucket, and the great expense in replacing them, especially if the bucket door is drowned; because all the rods must be drawn to the surface, which requires long time and necessitates the employment of a great number of men when the lift is deep.

Second. When the water is saline or acidulous, which is very often the case in Cornwall, the working-barrel is soon eaten away, which causes unevenness in the bore of the barrel, and causes a great leakage.

These are very serious objections, especially in mines where continuous working is an absolute condition.

For *Naphtha*, any type of pump will do, but they must be made of cast iron.

For *Oil*, the double-acting piston pump will do, but by far the best are of the single-acting plunger type; they should be made wholly of gun-metal.

For *Paper Pulp*, the double-acting piston pumps, or treble-barrel plunger pumps, made of cast iron.

For *Paint*, double-acting piston pumps or plunger pumps, made of cast iron, buckets or pistons fitted with cast-iron packing rings.

For *Petroleum*, single-acting bucket pump. The pump barrel is usually made of gun-metal or brass, but sometimes of cast iron, brass lined; the suction and delivery pipes are of wrought iron, the pump-rods are frequently made of wrought-iron tubes screwed together. Their diameters vary from 2 to 3 inches. They are worked by a tee bob or by a crank.

For *Salt Water*, any type of pump will do; all parts must be made of gun-metal, the alloy for which is given on page 42.

For *Sewage*, double or treble-barrel plunger pumps and double-acting plunger pumps, made of cast iron. The treble-barrel pumps give the nearest approach to equal flow, and consequently equal resistance, but on account of increased first cost, and the friction due from the three barrels, buckets and rods, it is better, whenever possible, to employ double-barrel pumps or double-acting piston pumps, and provide a heavy fly-wheel to equalise the resistance.

For *Sugar Solution*, double-acting piston pumps, and single, double, or treble-barrel plunger pumps, all parts made of gun-metal.

For *Tanneries*, single or double-barrel plunger, or piston and plunger pumps, made of cast iron, and barrels of brass, or lined with brass.

For *Tar*, see Gasworks, page 18.

For *Treacle*, see Sugar Solution, page 21.

For *Vinegar*, any class of pump will do, but they must be made of lead, glass, guttapercha, or stoneware; same as for acids, pages 16 and 17.

For *Waterworks*, double-acting piston pumps, bucket

Author will give only a few samples of the best and most commonly used.

The oldest valve is probably the metal clack-valve, as it is mentioned and illustrated in "Hero's" work on Pneumatics, written about the year 200 B.C. The most common is the leather clack-valve, which consists of a piece of leather or canvas covering an orifice and held down at one edge, which forms a hinge; the leather is at the centre covered top and bottom by metal plates, to make it rigid, and to add weight, so as to enable the valve to close.

The most simple valve for ordinary hand-pumps and pumps for very low lifts, is illustrated in Figs. 17 and 18, Plate V. It consists of a piece of leather or canvas cut to the same size as the diameter of the bottom flange of the pump-barrel, and a piece to the shape shown at A cut out; this slit must be cut so that a lap of one-tenth of an inch for every inch of the diameter of the waterway is allowed all round; a plate of wrought iron, cast iron, or gun-metal of the same diameter, should be placed on the top of the valve, and a plate of the same material a little less in diameter of the waterway must be placed on the bottom side, the two plates and the leathers are fastened together by a bolt or rivet, the former being preferable, as when the leather is worn out the nut can be unscrewed in a few minutes and a new leather put in. These valves should never be allowed to rise higher than an angle of 30° from the seat, and 60° from the horizontal line.

The Butterfly Valves.—These derive their name from the fancied resemblance to the wings of a butterfly, and are made in many different ways, some being of leather and canvas, with hinges formed out of the same piece; others of cast iron, wrought iron, or gun-metal clacks or flaps

faced with leather, canvas, indiarubber, guttapercha, or vulcanised fibre, to reduce the severity of the concussion ; others have beats of compressible substances fixed in the seat. Figs. 20, 21, and 22, Plate V., illustrate the best design of this type. A is the seat, B the guard, which prevents the clacks from rising too high ; *c c* are the two clacks hinged on a pin ; the holes in the clacks through which the pin passes are made oval, so that the clacks lift one-eighth of an inch perpendicular before they commence turning on the pin.

These two types of valves open by moving from a fixed point or hinge, therefore the lift or opening must be taken at the centre, and the periphery opposite the hinge of the valve passes through an arc double the length of the lift, consequently the valve takes a long time in closing, thus allowing a great amount of water to slip back into the suction-pipe before it has time to close, and a heavy concussion is produced. Valves of this class should be fixed in such a way that they open in the direction in which the water has to flow into the working-barrel ; this prevents any change in the direction of the flow of the water.

Double-beat Clack-valves.—One form of this class of valves is illustrated in Fig. 19, Plate V. It consists of an ordinary clack-valve and seat, but having a hole half the area of the clack cut out of the top of it, this hole being covered with an ordinary clack-valve. Both these valves open in the same direction.

A modification of the above-described valve is shown in Fig. 23, Plate V. This valve is noiseless in its action and cheap. It consists, like the previous valve, of two clacks, but having the small one hung in the opposite direction. In this valve the area of the top clack is one-third the area of the opening in the main valve seat.

Valves with a perpendicular lift are mostly used for horizontal pumps, especially for waterworks. The most simple and best of this type is shown in Fig. 24, Plate V. This valve is called the conical mitre-valve. It consists of a conical shell, the sides of the cone being at an angle of 45° , the top part is turned to fit the bevel in the top of the seat, the lower part of the cone is furnished with three or more wings or guides, according to the size of the valve, these guides should be put at such an angle that the valve at every rise will partially rotate so as to wear the seat evenly and prevent any grooves being formed. Inside the cone is cast a short spindle, which beats against a stop provided in the pump-valve box.

This design of mitre-valve is by far the best, the flow of water being brought into the proper direction by reason of the cone causing less obstruction to its passage, and producing less contraction of the fluid vein than the valve illustrated in Fig. 25, Plate V. This valve consists of a slightly convex gun-metal disc, the periphery of which is bevelled to correspond with the seat, furnished with guides at its under side, and on the top side a spindle working in a guide above; and between the valve-plate and the bottom of the guide are placed alternately india-rubber rings and small round cast-iron or gun-metal washers; this arrangement forms a buffer spring, which diminishes to the least degree the knock produced by the valve at the end of its lift, it also assists the valve in closing on the return stroke—a most important feature, thereby adding an increased efficiency of the pump by reducing the amount of slip. Short indiarubber tubes are sometimes used in place of the rings and washers, also steel and brass springs, according to the chemical properties of the fluid to be raised by the pump. In all cases where springs are used a certain free lift should be given to the

valve, and the remainder should be obtained by the compression of the rubber rings or springs.

The surface of contact between the valve and its seat should be made perfect by grinding-in the valve after the seat has been fitted into its place. When both the valve and seat are of metal, without the intervention of loose beats, the valve and seat should be made of the same metal, otherwise a galvanic action is produced, causing corrosion of that surface, forming the positive element.

The spindle or spill-valve is represented by Fig. 27, Plate VI. It is similar to the last mentioned, with the exception that the guide on the under side consists of a round spindle or spill, working in a boss in the centre of the seat, fixed to the latter by ribs or webs. The objection to this valve is that the boss and its ribs take up a large portion of the waterway.

Sometimes these valves are made with a cone or hemisphere instead of a convex disc, as shown in Fig. 26, Plate VI.

A very useful valve for impure or thick fluids, such as tar, treacle, paper pulp, tan liquor, &c., is depicted in Fig. 28, Plate VI. It has a perpendicular lift, but, as will be discerned, has not any guides. It consists simply of an inverted bell without a clapper, hence its name, bell-valve, beating on a slightly countersunk seat. The bottom of the bell is made heavy, so that the centre of gravity is always below the bottom of the seat, guides not being then necessary. The top part only requires to be turned.

Another valve suitable for pumping sewage is illustrated in Fig. 29, Plate VI. It consists of an annular ring, which slides up and down a cylindrical guide secured to the valve-box cover, round the bottom part of the valve outside is secured a hard wood ring; to the inside of the

seat is also secured another hard wood ring, and the valve, instead of beating on the top of the seat, enters into it, to cut off any stringy matter that might be on the seat when the valve closes. The valve is prevented from rising too high by its ring coming in contact with the cover, and prevented from dropping too low by the ledge at the bottom of the guide cylinder.

Double-beat Valves.—These valves are either of gun-metal or cast iron, the latter being mostly used for large valves. They have two beats; one at the top, and one at the bottom: the area of the top seat should not be less than one-half the area of the bottom beat. In most of the London waterworks' pumps white-metal beats are employed; wood beats are frequently used, and of this class *lignum vitæ*, with the grain upwards, is the best, but beats made of the best English bark-tanned leather fixed to the valve and beating against a gun-metal seat are without any doubt the most durable valves for heavy pumping. Valves of this construction have been working for twelve months under heads of from 600 to 1000 feet in dirty water without requiring new leather beats.

This valve is illustrated in Fig. 30, Plate VI. The seating consists of a circular ring, on which the lower part of the valve beats, and a circular plate of about one-half the area of the bottom ring, on the outer edge of which the upper part of the valve beats; on the upper side of the top plate is cast a spindle, which rests against a boss on the under side of the valve-box cover. These two plates are joined together by three or more ribs or webs, according to the size of the valve. The valve itself may be described as a double cylinder, one contained within the other, but forming one entire piece, open top and bottom, the area of the top opening being less than one-half the area of the bottom one. A boss is provided above

this cylinder, joined to it by three or more ribs, to form a guide working on the spindle at the top of the seat. The ribs should be put at such an angle, that the influx of water causes the valve to slightly rotate every time it rises and falls.

It is necessary to be particular in the measurements of the areas of the two seats, for the calculations relating to the suction and delivery valves. The diameters should be measured thus:—Take the *inside* diameter of the *lower* seat, and the *outside* diameter of the *upper* seat to determine the area upon which the water acts in opening the valve. If we assume the exterior diameter of the upper seat to be 9 inches, and the interior diameter of the lower seat to be 11 inches, then the difference of area will be:

$$95.033 - 63.617 = 31.416 \text{ square inches,}$$

and this represents the area upon which the water must act in opening the valve.

A valve of such dimensions would weigh about 100 lbs., hence the pressure requisite to open the suction valve would be:

$$\frac{100}{31.416} = 3 \text{ lbs. per square inch.}$$

In this calculation no allowance has been made for the reduction of pressure requisite to open the valve due to the fact of its immersion in water; this reduction would amount to about one-seventh of the weight. In the case of the upper valve there is, of course, the weight of the column of water upon the valve to be overcome in opening it in addition to its own weight.

The column of water thus acting upon the delivery valve is annular, having a base bounded by two circles,

the smaller being equal to the diameter of the *inside* edge of the top beat, and the larger circle being equal to the *outer* edge of the bottom beat. When the valve is open, this last element may be regarded as not acting upon it, as it will with the rest of the water be flowing away, driven by the stream issuing from the pump.

The amount of work actually done in opening the valve is, of course, equal to its specific weight multiplied by the distance through which it is raised.

Taking the weight of each valve as 100 lbs. and its lift 2 inches, we find the amount of work done throughout the stroke for each valve thus:—Obtain the specific weight of each valve by subtracting from it one-seventh of its weight:

$$\frac{100}{7} = 14.28; \text{ then } 100 - 14.28 = 85.72 \text{ lbs.,}$$

the lift of the valve = 2 inches = $\frac{1}{6}$ foot,

hence the work done will be

$$85.72 \times \frac{1}{6} = 14.286 \text{ foot lbs.}$$

for each valve, and for the two valves at each stroke it will be

$$14.286 \times 2 = 28.572 \text{ foot lbs.}$$

If we, for example, take the area of the pump plunger to be 1 square foot, the stroke 8 feet, and the *head of water* against which the pump is working 100 feet. The quantity of water raised at each stroke of the engine will then be 8 cubic feet; and as 1 cubic foot of water weighs $62\frac{1}{2}$ lbs., the weight of water raised by the engine each stroke will be

$$= 62\frac{1}{2} \times 8 = 498 \text{ lbs.};$$

this load being raised to an average height of 100 feet, the amount of work done equals

$$498 \times 100 = 49,800 \text{ lbs. per stroke.}$$

From this amount must be deducted the power absorbed in opening the valves, viz.: 28·572 foot lbs.

$$49,800 : 28\cdot572 = 100 : 0\cdot057 \text{ per cent.}$$

This is to all appearance the work absorbed by the valves; but it is evident that more is lost, because the valve is kept open during a period equal to the time occupied by the up-stroke of the plunger by means of the water passing through it; and although it may be chiefly in the form of friction, yet the work is lost, and does not appear in the useful effect.

Allowing for the reduced weight of valve due to its immersion, it is found that the pressure required to keep it suspended is $3 - \frac{3}{7} = 2\cdot572$ lbs. per square inch, which represents the difference between the pressure above and below either valve, when open, and which must of course act over the whole area of the pump plunger.

The pressure due to a column of water of 100 feet in height

$$= 100 \times 0\cdot433 = 43\cdot3 \text{ lbs. pressure per square inch,}$$

and the percentage of pressure added to this will be

$$43\cdot4 : 2\cdot572 = 100 : 5\cdot9 \text{ per cent.,}$$

or nearly 6 per cent. of the work done by the engine.

Let us now compare this loss with that of an ordinary clack delivery valve of the Butterfly type, 20 inches in diameter, the extreme opening of each clack being 6 inches, and the height of delivery column 100 feet, above the

valve, then the pressure of water will be

$$= 0.433 \times 100 = 43.3 \text{ lbs. per square inch,}$$

the area of each clack will be

$$= \frac{20 \times 20}{2} \times 0.7854 = 157 \text{ square inches,}$$

hence the total pressure exerted by the water on each clack will be

$$= 43.3 \times 157 = 6798.1 \text{ lbs.}$$

Assuming the valve-clack to weigh 300 lbs., the total weight in action on each clack will be

$$= 6798.1 + 300 = 7098.1 \text{ lbs.}$$

The work done by the descent of this weight will be equal to its intensity (7098.1), multiplied by its mean distance of fall in feet, which must be calculated from the centre of gravity of the semicircular clack. The centre of gravity of a semicircle is nearly 0.425 of the radius distant from the diameter bounding the semicircle; hence, in the present case, the space passed through by each part of the clack being proportional to its distance from the diameter, and the extreme space being assumed at half a foot, the work done on each clack will be

$$= 7098.1 \times 0.5 \times \frac{10 \times 0.425}{10} = 1508.34 \text{ lbs.,}$$

and the total work expended on the valve seating due to the action of the two clacks will be

$$= 1508.34 \times 2 = 3016.68 \text{ foot lbs.}$$

The advantages of this valve are its diminished rise, which reduces the concussion, also its lower percentage of "slip." It has, however, the objection, when it beats on

hard faces, that from the circumstance of the two faces being inseparably connected, any dirt, grit, or foreign matter getting between either of the beats will cause considerable leakage in both.

In all valves of this kind the ribs at the top of the shell or the valve itself should be inclined a little from the perpendicular, so that the water in passing through the openings may impart to it a gradual circular motion, which tends to keep the beat perfect, and prevent the formation of grooves.

There are many variations of this class of valves, but the difference is so slight that it is not necessary to illustrate or describe them in this little work.

A valve of the multiple beat description is shown in Fig. 31, Plate VI. It has three beats, and consists of a seat securely fixed in the bottom of the valve-box or clack-seat; in the centre of this seat is formed a boss, into which is fixed a centre-spindle, upon which works three separate valves of the annular type, the bottom one beating on its seat, the top side forming a beat for the second one, and so on, the top valve is furnished with a boss having a covered top to prevent leakage through the same.

It is evident that a valve of the ordinary construction must be lifted from its seat three times as high as this valve in order to allow the passage of the same quantity of water, in the same time, and under the same pressure; because in the rising of this valve each portion opens separately, and consequently has to lift but one-third of the total height; also from the fact of there being a ring of water between each part, they will shut uniformly together until the lower part reaches its seat, when it becomes a seat for the next, and so on progressively, reducing the concussion in proportion to the number of

The diameter of the ball is found by multiplying the diameter of the seat opening by 134 and divide by 100.

Where cold water is being pumped these balls may with advantage be made entirely of indiarubber. Valves with gun-metal balls have been used for air compressors.

REMARKS ON DESIGNING PUMP-VALVES.

CLACK-VALVES.

All corners against which leather, indiarubber, vulcanised fibre, or canvas works, should be carefully rounded, to prevent any cutting edges.

Great care should be taken in the selection of the leather, when used either for hinges or simply for a valve facing; for hot water containing copper in solution only the very best bend hides should be used. Good leather, being hard in texture, of a light colour, and presenting a shiny appearance when cut with a knife. Inferior hides are dark coloured, approaching a brownish yellow, and are inclined to sponginess. The harder and firmer the leather the better. In cutting out clack leathers the best portion should be reserved for the front of the clack, where the beats wear most. Leather-hinged clacks often give way at the hinge; attention, therefore, to the quality of the leather for that part is necessary.

The clack when open should make an angle of 80 degrees with its seat, and should never be allowed to exceed an angle of 60 degrees upon any consideration.

The width or lap of beat, that is, the part of the valve which rests on the seat, should be $\frac{1}{16}$ th of an inch for every inch in diameter of the seat opening; for example, a 10-inch valve should be 12 inches in diameter, having a lap all round of 1 inch.

The clack should be allowed to lift perpendicular from its face or seat before it commences turning on its centre or pin.

MITRE-VALVES.

The angle of the mitre or bevel of the edge of the valve is usually made at an angle of 45 degrees, for it has been found that if the angle be greater the valve has a tendency to *set* in its seat, and if less, an unnecessary space is given to the valve, and a greater pressure will be required to open the valve when closed. When these valves are used in air compressors the angle is sometimes made 60 degrees.

The width of the beat should never be made more than $\frac{1}{4}$ of an inch for the largest size, and for small sizes $\frac{1}{8}$ of an inch is sufficient.

The diameter of the top plate of the valve should never be made larger than the largest diameter of the mitre in the seat.

If the valve is provided with a spindle on the top or bottom, the valve should always be cast with the spindle downwards, to ensure the casting being sound.

Great care should be exercised when designing metal valves of any description to have uniformity of thickness throughout it, and if any inequality is necessary, it should be made gradually, so that there will be no danger of drawing when the casting is cooling.

The lift of these valves should always be made as little as possible, to reduce the banging or hammering of them against their seats; in order to give the valve opening the same area as the seat, the valve should lift one-fourth of the seat's diameter, that is, a 4-inch valve should be allowed to lift 1 inch. If the diameter can be increased a less lift can be given; this is a most desirable feature, to increase the diameter of the valve and reduce the lift. The flow of water through the valve opening should not, if possible, exceed a speed of 200 feet per

minute. For heavy lifts the valve ought not to be allowed to lift more than one quarter of an inch.

The size of the valve-box for this class of valves can readily be obtained by adding the area of the outside diameter of the valve-plate to the area of the seat, the sum of these being equal to the area of valve-box required.

Valve Beats.—The valve beats are made of a composition of lead and tin, wood, leather, or guttapercha. Almost every kind of wood has been tried, the best being birch, holly, and lignum vitæ; oak will not do, on account of the tannic acid present. When the beats are of metal, they must both be made of the same metal, or else a galvanic action will take place, which will eat away the most magnetic metal. When loose beats are used they should be fixed in the valve, not in the seat.

Valves with perpendicular lift should have all the ribs and guides a little inclined from the perpendicular, that the water in passing through the waterway may give the valve a gradual circular motion, which tends to keep the beats perfect and prevent the formation of grooves. An inclination of half an inch in 6 inches is enough.

Indiarubber Valves.—The indiarubber disc should fit easy on the spindle, otherwise it has a tendency to break at the centre.

The guard should be of such a size that when the indiarubber strikes against it it cannot bend again round the edges, otherwise the disc will soon break round the periphery. The guard should be made two thicknesses of the rubber, less in the diameter of the disc; thus a disc 10 inches in diameter, $\frac{1}{4}$ an inch thick, requires a guard 9 inches in diameter.

The disc should be allowed to lift on the spindle from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, according to the diameter of the valve, before it is stopped by the guard.

A good radius for the curvature of the guard, with the before mentioned lift given to the disc, is the diameter of the disc; thus for a 10-inch disc $\frac{1}{2}$ of an inch free lift, the radius of the guard will be 10 inches.

All holes in the guard and grid should be well rounded, sharp corners presented to the indiarubber should be avoided.

For heavy pressures the width of the openings in the grid should be made equal to the thickness of the indiarubber disc, which should be proportioned to the height of the lift, and varies from $\frac{3}{8}$ to 1 inch and upwards in thickness, according to the quality of indiarubber used.

The ordinary indiarubber disc valve will not work economically with a heavier pressure than 250 feet head, but the rotating disc valves have worked for three years under a pressure of 490 feet and even then were in good working condition.

Quality of Indiarubber.—For cold water pure indiarubber is probably the best, but for ordinary pump-valves the indiarubber with a specific gravity half heavier than water is the best, because pure rubber is so light that the discs have to be forced down by the returning pressure of the pump on the suction-valve, and the rising column on the discharge or delivery valve.

BALL-VALVES.

The beating surface for ball-valves made of indiarubber, or metal covered with indiarubber or guttapercha, should be very broad, to prevent the indiarubber being cut; if this is attended to and no sharp edges are left on the seat, a good indiarubber ball will wear perfectly even all round.

If the ball is made of gun-metal the beating-surface need not be quite as broad.

The ball-valve will not work well against a heavier pressure than 200 feet head.

Valves used for hot-water pumps should be made one-half larger in diameter than the piston, or instead of one large valve several small ones, with an aggregate area corresponding to the same, in order to obtain a large water-way and a very small lift of valve.

When gritty or muddy water is pumped, there should be a chamber or recess formed in the valve-box round the valve seat, no matter what class of valve, to allow the grit, mud, or other impurity to gravitate into it, keeping the valve seat clear. A sludge-cock should be provided, so that the sediment can be blown-off at intervals.

MATERIALS OF WHICH PUMP-VALVES SHOULD BE MADE, AND CLASS OF VALVES FOR DIFFERENT LIQUIDS.

For *Strong Acids*, a flat piece of wood loaded with lead and guided at the sides, is by far the best; in some cases lead or glass seats with guttapercha discs have been used with advantage.

For *Ammoniacal Liquor*, the cast malleable iron mitre-valve is generally used, and sometimes the mechanically moved piston-valve.

For *Anthracene Oil*, cast malleable iron mitre-valves.

For liquid *Asphalt*, cast malleable clack-valves, or mechanically moved piston-valves.

For *Benzole*, gun-metal mitre valves or gun-metal clack valves.

For *Benzoline*, the gun metal mitre-valve is recommended.

For *Bilge Pumps*, or other ship purposes, where *salt water* has to be pumped, gun-metal valves of the mitre type, or clack-valves of gun-metal, are largely used. Indiarubber ball-valves have also been frequently employed. The best alloy for the gun-metal consists of:—

Copper	..	..	..	..	88	per cent.
Zinc	..	..	..	..	2	„
Tin	..	..	..	..	10	„

For *Breweries*, any class of valve will do, but clacks are very sluggish in their action, consequently allowing a great deal of slip; they should be made of gun-metal.

For *Creosote*, cast malleable iron clacks or mitre-valves.

For *Fire Engines*, almost any type of quick closing valves will do; some makers prefer rectangular clack valves, with indiarubber rings, to ensure a quick closing; others use indiarubber disc valves; and again, one or two firms employ indiarubber ring valves of the "Field" patent type.

For *Gelatinous Fluids*, not containing acid, gun-metal clack valves; but if there is acid present a large proportion of lead should be used in the gun-metal alloy.

For *Glutinous Fluids*. If the fluid is very thick, mechanically moved piston-valves, or clack-valves made of cast iron, or the bell-valve, will be found to answer remarkably well; but if very thin, cast malleable iron mitre-valves will do.

For *Hot Water*, gun-metal mitre valves and specially prepared indiarubber discs, also vulcanised fibre manufactured for that purpose.

For *Hydrochloric Acid*, mitre valves of Hargreave and Robinson's patent white metal, or an alloy consisting of:—

Lead	1 pound
Tin	1 ounce
Antimony	1 ounce, well mixed together.

For *Milk of Lime*, gun-metal clack valves or bell valves.

For *Mines*. The classes of valves mostly used are the Clack and Butterfly valves, on account of cheapness and ease in repairing. The double clack-valve, illustrated in Fig. 20, Plate V., and described on page 24, is very good; but the double-beat valve made of gun-metal with leather beats fixed on the valve (not on the seat), is the best for moderate size pumps; they have been known to work well for twelve months under heads of 600 to 1000 feet in

dirty, gritty water, without new leather beats being required.

For *Naphtha*, cast iron or cast malleable iron mitre-valves.

For *Oil*, gun-metal mitre or clack valves.

For *Paper Pulp*, cast-iron bell valves, cast malleable bell-valves, or wrought or cast malleable clack-valves.

For *Sewage*. The best valves for sewage are the clack-valves; they should be made in groups of several small ones, having a collective area equal to one-and-a-half times the area of the plunger; the valves should be rectangular, from 4 inches by 9 inches to 9 inches by 18 inches. The valves should be made of cast or wrought iron faced with leather or vulcanised fibre. For small sewage pumps the bell-valves answer well.

For *Sugar solution* and *Treacle*, the clack-valves or mechanically moved piston-valves are the best; the clack-valves act best when they are hung at an angle of 70 degrees to the horizontal line; they should be made of gun-metal beating against gun-metal seats.

For *Tan Liquor*, gun-metal bell or clack valves, but the alloy must possess a great portion of lead, on account of the tannic acid present in the oak bark contained in the liquor.

For *Tar*, the best valves are the mechanically moved piston-valves, or the mitre-valve type made of cast malleable iron. The bell-valves have also been found very serviceable for tar.

For ordinary small pumps for raising *Water*, the most appropriate are of the gun-metal mitre type, indiarubber disc valves, and leather clacks. Indiarubber ball valves, loaded in the interior with lead, have been used for elevating water containing sand and grit.

For *Waterworks*, the best valves for small pumps with

little lift are gun-metal mitre valves with gun-metal beats and seats. For small pumps with heavy lift, gun-metal mitre valves and seats with guttapercha beats. For pumps of a moderate size, Cornish gun-metal double-beat valves with gun-metal seats and beats. For very large pumps, multiple beat valves with wood or white metal beats should be employed.

PUMP BUCKETS.

There are as many varieties of pump buckets as there are different classes of valves; the Author will therefore confine himself to a few of the most commonly used, giving a sample of each class.

Figs. 39 and 40, Plate VII., illustrate an ordinary *hand pump bucket*, packed with a *cup-leather*. It will be seen that it consists of a body casting, forming a boss at the top, into which the bucket-rod is screwed; by means of a ring screwed on the bottom of the body the cup-leather is secure. The valve consists of a piece of leather fixed firmly to the bucket body by means of two screws, and the leather is furnished with a top and bottom plate secured by a centre bolt and nut or rivet, the bolt being the best, as a new leather can be easily put in its place when the old one requires renewing. A stop should always be provided, to prevent the valve rising too high; this can be done by allowing the bucket-rod to protrude sufficiently below the boss, into which it is screwed, or by making the projection on the under side of the boss, as illustrated.

Figs. 41 and 42, Plate VIII., are illustrations of a bucket fitted with butterfly clacks. The arrangement of the clacks is identical with those in the valve (Figs. 20, 21, and 22, Plate V.). This bucket is made of brass, and the lids faced with leather, the hole in the bucket-rod, through

which the hinge-pin passes, is slightly oblong, to allow the clacks to lift perpendicular in opening; the pin is secured endways by a cotter; but should the cotter by any means slip out of its place, the hinge-pin cannot get out so long as the bucket is in the working-barrel. The top part of the bucket is made large enough to fit the working-barrel. The hoop at the bottom of the bucket is also turned to fit the working-barrel. The leather is placed on the bucket in the usual manner, and covered by the hoop below; by this means the leather is prevented from wearing on one side of the bucket, as sometimes occurs, and the leather acting solely as the water-tight joint between the flange on the top and the hoop on the bottom of the bucket. The bottom ring is kept in its place by a cross-piece and cotter.

The ordinary *clack bucket*, as used in the Cornish pumps, is shown in Figs. 43 and 44, Plate VIII. It consists of a bucket-shell or body, usually made of cast iron, but of brass when acidulated water is being pumped; the outside of this shell is covered with a leather ring, and the bottom part of this ring is surrounded by a wrought-iron ring, held in its place by a cross-bar and cotters; through the former passes the fork end of the pump-rod, which is held to the bucket by the same cotters. The valve is of the ordinary clack type, made to lift freely in the guides before it is allowed to turn on its pins.

A bucket fitted with *Indiarubber disc valve* is depicted in Fig. 45, Plate VIII., the packing rings in this case being made of gun-metal, forced against the face of the working barrel by means of a spiral spring. The grid or grating, the bucket-shell and the valve-guard, are all held firmly together between a fixed collar on the top side of the bucket-rod, and a nut and cotter at the bottom.

A bucket fitted with *hemp packing* is shown in Fig. 38,

Plate VII.; it consists of a bucket-shell secured on the bucket-rod by means of two nuts; the valve is of the conical perpendicular lift type, guided by the bucket-rod, which latter is enlarged at that place, and a fixed collar on the rod determines the lift of the valve. A ring fitting the top part of the bucket-shell is furnished with three legs, joined at the top by a boss bored to fit the bucket-rod. The packing consists of hemp plaits, dipped in tallow prior to its being plaited; the hemp plaits are carefully twisted round the bucket-shell and pressed together between the ring and the collar provided round the bottom of the shell by means of the nut above the boss of the ring.

REMARKS ON PUMP BUCKETS.

The buckets should always be made of the same material as the pump valves.

The bucket valves should always, if possible, be of the same type as the suction and delivery valves.

The cup-leathers should be most carefully made of the very best leather that can be procured ; this will be found to prove the cheapest in the end.

The same remarks on the leathers for the valves, on page 37, also apply to the bucket leathers and valves.

PUMP PISTONS.

The most common pump piston is illustrated in Fig. 46, Plate VIII. It consists of two cast-iron or gun-metal plates, turned all over, and bored at the centre to fit the pump-rod ; another plate of gun-metal, turned all over and bored out to fit the piston-rod in small pumps, but in large ones it is bored to fit a boss or nipple on the inside of the two outside piston-plates ; between these two plates is fixed the *cup leathers* ; the outside plates must be carefully rounded at the corners, which fit against the cup leathers, and the centre plate must also be turned to accurately fit the outside corners of the leathers, this prevents them altering their shape at each reciprocating motion of the pump piston. The leather of which the cups are made should be selected from the very best English oak-bark-tanned bend hides, and carefully pressed in a mould. For description of the process of making the cup-leathers, see page 52.

A very good packing for pump-pistons raising gritty and dirty water is illustrated in Fig. 47, Plate VIII. It consists of two piston-plates of cast iron, between which are fixed rings made of the best bend leather hippopotamus hide. The leather rings are put in their places, the piston fixed on the rod, and the nut tightened up, afterwards the whole is put in a lathe, and the leather turned perfectly true. This packing wears better than any other in gritty water, and is in daily use in many collieries.

Another type of pump-bucket is illustrated in Fig. 48, Plate IX. It consists of two piston-plates, turned in the groove for *metallic packing rings*, instead of leather packing, and bored out to fit the pump-rod. In this and all the other types of pump-pistons the rod is usually reduced in diameter on that part which passes through the piston, and the end beyond the back of the piston is screwed and provided with a nut, which latter is prevented from working loose by a split pin or cotter, passing either through the nut or just behind it; in that case the rod is weakened, first by turning it less in diameter, secondly by screwing it for the nut; again, it forms of necessity, a very small shoulder, which, if the piston is the least slack on the rod, soon works itself into the piston, and causes a leakage. The best way of securing the piston on the rod is that shown in Fig. 46, Plate VIII., which consists of two nuts; the piston-rod is screwed up, and one nut screwed on tight and secured by a split pin driven through the nut; the piston-plates are next put on to the rod, and then the second nut is screwed on, and prevented from getting loose by a taper-split cotter, the cotter hole being made long enough for tightening in case of wear. This style of fastening the piston on the rod has the double advantage of forming a large shoulder, and only weakening the rod by screwing it for the nut. The packing rings are made

in different ways. The simplest form is shown in Fig. 48, Plate IX. They consist of two cast-iron or gun-metal rings (according to the class of liquid to be pumped) turned a little larger in diameter than the bore of the pump-barrel, and cut across at an angle of 45 degrees.

A more complicated and expensive class of packing is illustrated in Fig. 45, Plate VIII. It consists of two rings of gun-metal; these rings put together form a channel, into which is put another ring cut into a spiral, this latter ring presses the two outer rings laterally, and by that means make a tight joint between the piston-plates and the outer rings. The two outer rings are made larger in diameter than the bore of the barrel, and are cut across at an angle of 45 degrees; there should be in both cases a small peg fixed in each of the outer piston-plates, so that the cross cuts of the two rings do not come in a line, and to prevent the rings from turning round.

Another good *metallic packing* ring consists of one broad ring only, turned a little larger in diameter than the bore of the working-barrel; it is, in the manner shown in Fig. 49A and B, Plate IX. The opening should be the same as the difference between the circumference of the ring before it is inserted into the working-barrel and the circumference of the working-barrel. The process for making this ring is as follows:—First mark off and drill holes, as indicated by the dotted circles in Fig. 49A, Plate IX.; next saw it along the dotted line, joining the two rows of holes; then file it until it assumes the shape shown in full lines in Fig. 49B, Plate IX.

All these types of metallic packing rings must be turned all over and carefully fitted into the recesses in the pistons. The separate plates of the pistons are held together by the nut on the piston-rod in small pumps, but the large pump-

pistons are fitted with junk rings, like ordinary steam-pistons.

The simplest pump-piston is illustrated in Fig. 51, Plate IX. It consists of a plain cylinder, turned all over, bored and fitted to the piston-rod; a series of recesses or grooves are next cut round the circumference. This piston acts very well for small quick-running pumps; the leakage is very little, because the loss of energy of motion of the fluid at each sudden enlargement of the annular spaces is very great, and therefore does not give the liquid time to pass between the piston and the circumference of the pump-barrel.

The last type of piston necessary to mention in this little work is shown in Fig. 50, Plate IX. It consists of two castings, turned and fitted, and bored accurately to fit the pump-rod. It will be seen that there is a groove formed between the two castings, into which is carefully twisted plaited hemp steeped in tallow. The packing is tightened up by the nut on the piston-rod. There must be two holes drilled and tapped into the back piston-plate to facilitate the removal of it, two hand screws can be inserted for the purpose when the piston requires to be repacked.

In some designs for this class of packing the piston consists simply of one casting turned with a simple groove round the circumference, without any means of adjustment.

CUP-LEATHERS.

The simplest form of mould for making cup-leathers is illustrated in Figs. 52 and 53, Plate IX.

In making the cup-leathers, the grain of the leather, that is, the outside of the hide, must be the working side. The leather should be carefully selected from the very best bark-tanned hides, the most suitable portion being the hard part of the butt for large leathers, and the shoulders for small leathers. The soft inner portion must be removed with great care by a sharp knife or a plane. Cut out a circle the size required for the leather and a hole in the centre to fit the bolt (this bolt forming the guide for the leather), then the piece must be carefully gauged, and if it is not equal thickness all over it must be planed until it is. When an even thickness is obtained the leather must be steeped in soft water until it is soft and flexible. While in this condition place the leather on the top of the collar, the die on the top of the leather, and the centre-bolt through the whole; then tighten the nut very gradually, until the top die is screwed down to the bottom. The mould must then be left to allow the leather to become thoroughly set. Then fix the leather in a lathe and by means of a shape-chisel or leather-knife cut it level, and bevel off the inside edge. When completed it should be well greased with tallow to keep it moist and ready for use.

AIR-VESELS.

The purpose of the *air-vessel* is to correct the intermittent discharge of the water into a continuous one, in order to prevent the concussion to the machinery caused by the force required to overcome the inertia of the water, and to economise the power of the engine by keeping the water in constant motion, thereby increasing the delivery of water when the pump-pipes are smaller than the pump-barrel. By the use of the air-vessel small delivery pipes already fixed may be retained when larger pumps or working-barrels are required. Where the lift is high and the delivery pipe large, as is the case of large pit pumps in mines, there is no necessity for air-vessels.

For size of air-vessel required for different classes of pumps, see Rules and Formulas, page 62.

There are three distinct classes of air-vessels: one consists of a large cylinder contracted at each end to the diameter of the rising main or delivery pipe, and having a pipe inserted for the delivery of the water. This pipe is brought nearly to the bottom of the chamber, leaving an annular space for compressing the air in; this pipe is called the *dip pipe*. This class of air-vessel is not very good, because the air rising in the most direct way allows very little of it to rise into the annular space.

The second class consists of a large pipe with a semi-circular or hemispherical top; the bottom is closed and provided with one inlet and one outlet branch.

The third consists of a large pipe with hemispherical top, provided with a branch at the bottom and another on the side.

The air-vessels are generally made completely of cast-iron. Sometimes a cast-iron base is used and the vessel proper made of wrought-iron and steel plates, riveted or welded together in the seams.

In large air-vessels an arrangement should be made for charging it with air when the pump is working. In that case the air-vessel is divided into two parts longitudinally by a diaphragm. The bottom part is furnished with a blow-off cock. A pipe fitted with a wheel-valve is furnished, putting the bottom part of the top chamber in communication with the bottom part of the bottom chamber. Another pipe forms a connection between the top part of the upper chamber and the top part of the lower chamber. This latter pipe is furnished with a wheel-valve for closing the communication between the two chambers, and below the valve is fixed, in the same pipe, a small valve communicating with the open air.

The operation for charging the vessel with air is as follows :—

Open the small valve communicating with the open air and the blow-off cock at the bottom chamber, to empty it of water and fill it with air.

Close the air and blow-off cock.

Open the valve which is fitted in the pipe communicating between the bottom of the top chamber and the bottom of the lower chamber, which causes the water to enter the bottom chamber from the top one.

Then open the valve on the pipe communicating between the top of the top chamber and the top of the lower chamber ; this allows the air in the lower chamber to rise into the top of the upper chamber. This being effected, close all the valves.

Should this not supply sufficient air, the process should be repeated.

A *manhole* is sometimes provided in large air-vessels for cleaning out mud and other sediment.

A *sifting valve* should be provided on the highest part of the air-vessel, for replacing the air which has been absorbed by the water.

A *glass water-gauge* should be provided to indicate the height of the water in the air-vessel.

RULES AND FORMULAS.

To find the Load on a Pump:—

Rule.—Multiply the area of pump in inches by the weight of the column of water in pounds per square inch.

Example.—Pump 3 inches in diameter; depth of well 30 feet:—

3 inches diameter = 7.06 inches area,

$$\frac{30 \times 44}{100} = 13.2 \text{ lbs. pressure per square inch,}$$

$$7.06 \times 13 = 91.78 \text{ lbs. total pressure on pump.}$$

To find the Force required to work the Lever of a Hand-pump:—

The leverage of a pump-handle is usually 6 to 1.

Rule.—Multiply the area of pump in inches by the weight of the column of water in pounds per square inch, this divided by the leverage of the lever equals the force required in pounds.

Example.—Pump 3 inches in diameter; depth of well 30 feet; leverage of handle 6 to 1:—

3 inches diameter of pump = 7.06 inches area,

30 feet = 13 lbs. pressure per square inch,

$$\frac{7.06 \times 13}{6} = 15.29 = 15\frac{1}{4} \text{ lbs. full.}$$

To find the Force necessary to work the handle of a Pump actuated by crank and handle:—

Rule.—Multiply the area of the pump in inches by the weight of the column of water to be lifted in pounds per

square inch, this divided by radius of handle divided by the throw of pump equals the force required in pounds.

The handle is usually 15 to 16 inches centres.

Example.—Pump 4 inches diameter; stroke of pump 8 inches; radius of handle 16 inches; depth of well 40 feet:

4 inches diameter = 12.56 inches area,

40 feet head = 17.3 lbs. pressure,

$12.56 \times 17.3 = 217.28$ lbs. total pressure,

8 inches stroke = 4 inches throw of crank,

$\frac{16}{4} = 4$ times leverage,

$\frac{217.28}{4} = 54.3$, say $54\frac{1}{2}$ lbs.

To find the Force necessary to work the handle of a Pump actuated by crank gearing and handle:—

Rule.—Multiply the area of a pump in inches by the weight of the column of water in pounds per square inch, the result divided by the radius of handle, divided by the throw of crank multiplied by the proportion of gearing, equals the force required in pounds.

Example.—Pump 4 inches in diameter; depth of well 40 feet; stroke of pump 8 inches; handle 16 inches centres:

4 inches diameter = 12.56 inches area,

40 feet head = 17.3 lbs. pressure per square inch,

$12.56 \times 17.3 = 217.28$ lbs. total pressure,

8 inch stroke = 4 inches throw of crank.

Gearing 2 to 1.

$\frac{16}{4} = 4$ times leverage of handles and crank, 2 to 1

gearing multiplied by 4 times leverage equals 8.

$\frac{217.28}{8} = 27.1$, say 27 lbs. force required.

A man turning a handle of a well frame will exert with comfort 20 lbs.

To find the Quantity of Water in gallons per minute delivered by a pump :—

Rule.—Multiply the diameter of pump in inches by itself and by 34, then by the piston speed of the bucket or plunger in feet per minute, and divide the result by 1000.

Example.—4 inches diameter of pump; bucket speed 100 feet per minute :—

$$\frac{4 \times 4 \times 34 \times 100}{1000} = 54.4 = \text{nearly } 54\frac{1}{2} \text{ gallons per minute.}$$

If the pump is *single-acting* the result has to be divided by 2.

$$\frac{54\frac{1}{2}}{2} = 27\frac{1}{4} \text{ gallons per minute.}$$

If the pump is *treble-barrel* one-half of the result must be added :

$$54\frac{1}{2} + 27\frac{1}{4} = 81\frac{3}{4} \text{ gallons per minute.}$$

If the pump is of the *bucket and plunger*, or piston and plunger type, it must be taken as a double-acting pump, and the diameter taken must be the diameter of plunger, not the bucket or piston.

To find the diameter of the Pump, when the quantity of gallons required and the bucket speed are given :—

Rule.—Multiply the bucket speed in feet per minute by 34, and divide the result into the number of gallons to be raised per minute multiplied by 1000, and the square root extracted out of the product will give the diameter of pump required in inches.

Example.—Required to raise 85 gallons of water per minute, at a bucket speed of 100 feet per minute :—

$$\sqrt{\frac{85 \times 1000}{34 \times 100}} = \sqrt{25} = 5 \text{ inches diameter of pump required.}$$

Approximate rule for quantity of water delivered by Pumps:—

Rule.—Multiply the diameter of the pump in inches by itself and by twice the bucket speed in feet per minute, the product will be approximately the quantity of water delivered by the pump per hour.

Example.—Pump 4 inches in diameter, run at a piston speed of 100 feet per minute:—

$$4 \times 4 \times 2 \times 100 = 3200 \text{ gallons per hour.}$$

There is no account taken of *loss by leakage* or "*slip*," nor *friction* in any of these rules; these vary greatly according to the class and condition of pump, if it is working against a high or low lift and the "*slip*" depending upon the class of valve used for the pump.

For well designed direct-acting horizontal pumps, one-tenth should be enough for "*slip*," for ordinary purposes, and 25 per cent. for *friction*, but when the suction is very long and the height to where the water is raised is great, one-third should be added; but if the pump is old and badly designed, as much as one-half must be added to the total amount required.

In an ordinary direct-acting steam pump one-fourth of the power required should be added, but if the delivery height is very great and the pipe very long one-half should be added.

To find the number of Horse-power required to raise a given quantity of Water in gallons to a given height in feet:—

Rule.—Multiply the given number of gallons of water to be raised per minute by 10 (which is the weight of one gallon) and by the height the water has to be raised in feet, and divide the product by 33,000.

Example.—100 gallons of water per minute to a height of 200 feet:—

$$\frac{100 \times 10 \times 200}{83000} = 6 \text{ horse-power.}$$

Note.—One-quarter to one-half should be added for friction.

To find the number of Horse-power required to raise a given quantity of Water in gallons to a given height in yards:—

Rule.—Multiply the given number of gallons of water to be raised per minute by 10 and by the height the water has to be raised in yards, and divide the product by 11,000.

Example.—100 gallons of water per minute to a height of 100 yards:—

$$\frac{100 \times 10 \times 100}{11000} = 9 \text{ horse-power.}$$

To find the number of Horse-power required to raise a given quantity of Water in gallons to a given height in fathoms:—

Rule.—Multiply the given number of gallons of water to be raised per minute by 10 and by the height the water has to be raised in fathoms, and divide the product by 5500.

Example.—100 gallons of water per minute to a height of 100 fathoms:—

$$\frac{100 \times 10 \times 100}{5500} = 18 \text{ horse-power.}$$

To find the diameter of Cylinder required for a direct-acting steam pump:—

Rule.—Multiply the area of pump-bucket or ram in inches by the pressure of water in pounds per square inch, and divide the product by the pressure of steam in

pounds per square inch, and add one-fourth to one-half for friction.

Example.—6 inches diameter of pump, 100 lbs. water pressure per square inch, 50 lbs. steam pressure :—

6 inches diameter = 28.27 inches area,

$$\frac{28.27 \times 100}{50} = 56.54 \text{ inches, area of steam-cylinder,}$$

add $\frac{1}{4}$ = $56.54 + 14.13 = 70.67 = 9\frac{1}{2}$ inches diameter of steam-cylinder, nearly.

To find the steam pressure required when the diameter of steam-cylinder, diameter of pump-cylinder, and water pressure are given :—

Rule.—Multiply the area of the pump in inches by the pressure of water in pounds per square inch, and divide the product by the area of cylinder, plus one-fourth for friction.

Example.—6 inches diameter of pump-cylinder, 100 lbs. water pressure per square inch, 70.88 inches area of steam-cylinder :—

$$\frac{28.27 \times 100}{70.88} = 39.8 + \frac{1}{4} = 49.7, \text{ nearly 50 lbs. pressure}$$

per square inch.

To find the thickness required for cast-iron pipes when the pressure is given in pounds per square inch :—

Rule.—Multiply the diameter of the pipe in inches by the pressure of water in pounds per square inch, and divide the product by 2000 or 3000, according to the quality of the iron.

Example.—10 inches diameter of pipe, pressure of water 346 lbs. per square inch :—

$$\frac{346 \times 10}{2000} = 1.73; \text{ or } \frac{346 \times 10}{3000} = 1.12.$$

SUCTION AND DELIVERY PIPES.

The *suction-pipe* should be larger than the *delivery pipe*, because *friction* is overcome in the *suction-pipe* by the atmospheric pressure only. In direct-acting steam pumps the *suction-pipe* is usually made about one-half of the area of the working-barrel, but if the pump is quick-running, required for raising thick liquids, or is very long, it ought to be made larger; in fact, in some cases they are made the same diameter as the working-barrel. In large Cornish plunger pumps the *suction-pipe* should be made large, as the suction-stroke is very quick, the rods being lifted by steam, and the water being forced up by the weight of the rods is rather slow.

The *delivery pipes* are usually made one-third of the diameter of the working-barrel, but if the pump is quick-running or the pipe very long, they should be made half the area of the working-barrel. A good speed for the water in pump-pipes is 200 feet per minute, but it should never exceed 400 feet per minute.

VACUUM VESSEL.

If the suction-pipe is very long the vacuum vessel should be placed on it, as near the pump as convenient; the air in it becomes expanded, and its elastic force causes the water to flow uniformly into the pump-barrel, and ensures it being properly filled at each stroke. The vacuum vessel should be at least twice the capacity of the pump-cylinder.

AIR-VESSEL.

An *air-vessel* should always be provided for heavy pressures or long delivery pipes. For ordinary pumps it should be three to four times the capacity of each stroke

of the pump, but for very heavy pressures and fire-engines it should be double that capacity.

The *position* of the *air-vessel* should be so chosen that the absorbed air can be replaced by the pump.

The *neck* of the *air-vessel* and *vacuum vessel* should be long and narrow, to prevent the water level in it being disturbed by the action of the pump.

SPEED OF PUMPS.

The speed of pumps varies according to circumstances and the class of liquid pumped.

Ordinary direct-acting steam pumps run at from 100 to 120 feet per minute.

Single, double, and treble-barrel pumps from 45 to 80 feet per minute.

Large pumps for mines run at an average speed of 130 feet per minute.

The *best speed* for large *pumping engines* is obtained by multiplying the square root of the length of stroke of the pump by 80.

SIZE OF PUMP-VALVES.

The pump-valves should be so much larger than the pipes, as to give a clear waterway the same area as the pipes.

LIFT OF THE VALVES.

The lift should be as little as possible without causing too much frictional resistance to the water; in any case the speed of the water through the suction-valve should not exceed 300 feet per minute.

To find the weight of cast-iron pipes approximately:—

Rule.—For a pipe, 9 feet long, and 1 inch thick, with a flange at each end, allow 1 cwt. for every inch of the

diameter, keeping the thickness and weight proportional either more or less.

Examples.—A 12-inch pipe, 9 feet long, flange at each end, 1 inch thick, will weigh approximately 12 cwt:—

A 12-inch pipe, 9 feet long, flange at each end, $\frac{3}{4}$ inch thick, equals 9 cwt.

A 10-inch pipe, 9 feet long, flange at each end, $\frac{1}{2}$ inch thick, equals 5 cwt.

HYDRAULIC MEMORANDA.

Weight of a cubic foot of water equals 62½ lbs.

Weight of a cylindrical foot of water equals 49 lbs.

Weight of 1 gallon of water equals 10 lbs.

One ton of water equals 36 cubic feet, nearly.

One gallon of water equals 277½ cubic inches, full.

Pressure in lbs. per square inch equals the head of water in feet multiplied by 434, and divided by 1000, or practically .44.

Head of water in feet equals pressure in lbs. per square inch multiplied by 2307, and divided by 1000, or practically 2.3.

FOR WATERWORKS.

Allow 15 to 20 gallons of water per head of population per day in non-manufacturing towns.

20 to 30 gallons per head in manufacturing towns.

Maximum demand 2½ times the average.

The mains should be large enough for double the average supply.

WORK DONE BY MEN AND ANIMALS.

Labourer turning a handle.—In working daily at a pump-handle, the average force is 14 lbs., moving at a rate of 220 feet per minute, equivalent to 3080 foot pounds per minute. 25 lbs. at the handle for short periods; but for continuous work a force of 15 lbs., moving through 220 feet per minute.

A labourer can turn the crank-handle from 25 to 30

times per minute, for a continuance, exerting a pressure of 20 lbs. at the handle; or he can apply a pressure of 28 to 30 lbs. for a short time, or from 50 to 56 lbs. at an emergency.

LABOUR OF HORSES.

Horses Raising Water.—23,412 foot pounds per minute for 8 hours a-day. 24,360 foot pounds per minute for 6 hours a-day. 27,056 foot pounds per minute for $4\frac{1}{2}$ hours a-day. 32,943 foot pounds per minute for 3 hours a-day.

A *Mule* working 8 hours will raise 10,000 foot pounds per minute.

An *Ass* working 8 hours will raise 3500 foot pounds per minute.

A pair of *well-fed Indian Bullocks* will raise 82 bags of water, 22 feet high in one hour, for a morning's work of $4\frac{1}{2}$ hours. Each bag contains $4\frac{1}{2}$ cubic feet of water, and the work is equivalent to 8000 foot pounds per minute.

The *speed* of an *Indian Bullock* is 2 miles per hour.

Length of a *Bullock walk* is 62 feet.

MODULUS OF PUMPS.

Common lift pumps	equal	·60
Pumps for drainage	„	·60
Fire engines	„	·57
Pumps for mines and deep wells	„	·66 to ·76
Three-throw pumps	„	·76
Waterworks pumps	„	·80 to ·90
Small centrifugal pumps	„	·25
Medium size centrifugal pumps		
for low lifts	„	·50
Large centrifugal pumps	„	·60

T A B L E S.

TABLE I.

QUANTITY OF WATER DISCHARGED PER MINUTE BY SINGLE-BARREL PUMPS, from 2 to 6-inch Diameter, at 30 and 40 Strokes per minute, 9, 10 and 12-inch Stroke.

Diameter of Pump.	9-Inch Stroke. Gallons per Minute.		10-Inch Stroke. Gallons per Minute.		12-Inch Stroke. Gallons per Minute.	
	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.
in. 2	3·0	4·0	3·33	4·44	4·0	5·3
2½	4·6	6·25	5·21	6·94	6·25	8·33
3	6·7	8·93	7·44	9·92	8·93	11·9
3½	8·83	12·2	9·81	13·55	11·77	16·26
4	11·96	15·9	13·28	17·66	15·94	21·2
4½	15·2	20·3	16·88	22·55	20·26	27·6
5	18·75	25·0	20·83	27·77	25·0	33·33
5½	22·69	30·25	25·21	33·5	30·25	40·33
6	27·0	36·0	30·0	40·0	36·0	48·0

TABLE II.

QUANTITY OF WATER DISCHARGED PER MINUTE BY DOUBLE-BARREL PUMPS, from 2 to 6-inch Diameter, at 30 and 40 Strokes per Minute, 9, 10 and 12-inch Stroke.

Diameter of Pump.	9-Inch Stroke. Gallons per Minute.		10-Inch Stroke. Gallons per Minute.		12-Inch Stroke. Gallons per Minute.	
	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.
in.						
2	6·0	8·0	6·66	8·88	8·0	10·6
2½	9·38	12·5	10·42	13·88	12·5	16·66
3	13·4	17·86	14·88	19·84	17·86	23·8
3½	17·66	24·4	19·62	27·10	23·54	32·52
4	23·92	31·8	26·56	35·32	31·88	42·4
4½	30·4	40·6	33·76	45·1	40·52	54·12
5	37·5	50·0	41·66	55·54	50·0	66·66
5½	45·38	60·5	50·42	67·0	60·5	80·66
6	54·0	72·0	60·0	80·0	72·0	96·0

TABLE III.

QUANTITY OF WATER DISCHARGED PER MINUTE BY TREBLE-BARREL PUMPS, from 2 to 6-inch Diameter, at 30 and 40 Strokes per Minute, 9, 10 and 12-inch Stroke.

Diameter of Pump.	9-Inch Stroke. Gallons per Minute.		10-Inch Stroke. Gallons per Minute.		12-Inch Stroke. Gallons per Minute.	
	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.
in.						
2	9·0	12·0	9·99	13·32	12·0	15·6
2½	14·7	18·75	15·63	20·82	18·75	24·99
3	20·1	26·79	22·32	29·79	26·79	35·7
3½	26·49	36·6	29·43	40·65	35·31	48·78
4	35·88	47·7	39·84	52·98	47·82	63·6
4½	45·6	60·9	50·64	67·65	60·78	81·11
5	56·25	75·0	62·49	83·31	75·0	99·99
5½	68·7	90·75	75·63	100·5	90·75	120·99
6	81·0	108·0	90·0	120·0	108·0	144·0

TABLE IV.

TOTAL PRESSURE IN PUMPS FROM 2 TO 6-INCH DIAMETER. HEIGHT OF DELIVERY FROM 10 TO 200 FEET.

Height of Delivery.	Diameter of Pumps.								
	2-Inch.	2½-Inch.	3-Inch.	3½-Inch.	4-Inch.	4½-Inch.	5-Inch.	5½-Inch.	6-Inch.
ft.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10	13·4	21·3	30·6	41·8	54·5	69·1	85·3	102·6	128·8
20	27·3	42·6	61·4	83·6	109·1	138·2	170·6	205·3	245·7
30	40·9	64·0	92·1	125·4	163·8	207·3	256·0	308·0	368·6
40	54·6	85·0	122·8	167·2	218·4	276·5	341·3	410·6	491·0
50	68·2	106·0	153·5	209·0	273·0	345·6	426·6	513·3	614·4
60	81·9	128·0	184·3	250·0	327·6	414·7	512·0	616·0	737·3
70	95·5	149·0	215·0	292·0	382·3	483·8	597·3	718·0	860·1
80	109·2	170·6	245·0	334·5	436·9	553·0	682·6	821·3	983·1
90	122·8	192·0	276·0	376·3	491·5	622·1	768·0	924·0	1106·0
100	136·5	213·3	307·1	418·1	546·1	691·1	853·3	1026·6	1228·8
110	149·9	234·6	337·7	459·9	600·6	760·2	938·6	1129·2	1351·6
120	163·8	255·9	368·5	501·7	655·2	829·3	1023·9	1225·9	1474·5
130	177·4	277·3	399·2	543·5	709·9	898·4	1109·3	1328·6	1597·4
140	191·1	298·6	435·9	585·3	764·5	967·6	1194·6	1431·2	1719·8
150	204·7	319·9	460·6	627·1	819·1	1036·7	1279·7	1533·9	1843·2
160	218·4	341·3	491·4	668·9	873·7	1105·8	1365·3	1642·6	1966·1
170	233·0	362·3	522·1	710·7	928·4	1112·4	1450·5	1745·2	2088·9
180	254·0	383·9	552·8	752·6	983·0	1244·1	1535·9	1847·9	2211·9
190	259·3	405·3	583·6	794·4	1037·6	1313·2	1621·3	1950·6	2334·8
200	273·0	426·6	614·2	836·2	1092·2	1382·2	1706·6	2053·2	2457·6

TABLE V.

PRESSURE OF WATER AT DIFFERENT HEADS IN LBS. PER
SQUARE INCH.

Head of Water in Feet.	Head of Water in Yards.	Head of Water in Fathoms.	Head of Water in Metres.	Pressure in Lbs. per Square Inch.	Head of Water in Feet.	Head of Water in Yards.	Head of Water in Fathoms.	Head of Water in Metres.	Pressure in Lbs. per Square Inch.
10	3.33	1.66	3.04	4.33	150	50.0	25.0	45.7	64.9
20	6.66	3.33	6.09	8.66	160	53.3	26.6	48.7	69.3
30	10.0	5.0	9.14	12.9	170	56.6	28.3	51.8	73.6
40	13.3	6.66	12.1	17.3	180	60.0	30.0	54.8	77.9
50	16.6	8.33	15.2	21.6	190	63.3	31.6	57.9	82.3
60	20.0	10.0	18.2	25.9	200	66.6	33.3	60.9	86.6
70	23.3	11.6	21.3	30.3	210	70.0	35.0	64.0	90.9
80	26.6	13.3	24.3	34.6	220	73.3	36.6	67.0	95.3
90	30.0	15.0	27.4	38.9	230	76.6	38.3	70.1	99.6
100	33.3	16.6	30.4	43.3	240	80.0	40.0	73.1	103.9
110	36.6	18.3	33.5	47.6	250	83.3	41.6	76.2	108.3
120	40.0	20.0	36.5	51.9	260	86.6	43.3	79.2	112.6
130	43.3	21.6	39.6	56.3	270	90.0	45.0	82.2	116.9
140	46.6	23.3	42.6	60.6	280	93.3	46.6	85.3	121.3

TABLE VII.

WEIGHT OF PUMP-PIPES, FROM 4 TO 24 INCHES DIAMETER;
9 FEET LONG, INCLUDING 2 FLANGES.

Diameter of Pipe.	Thickness.	Weight.	Diameter of Pipe.	Thickness.	Weight.
in.	in.	cwt. qrs. lbs.	in.	in.	cwt. qrs. lbs.
4	$\frac{3}{8}$	3 0 0	15	$1\frac{1}{2}$	18 3 0
$4\frac{1}{2}$	$\frac{3}{8}$	3 1 14	16	$1\frac{1}{2}$	19 0 0
5	$\frac{7}{8}$	4 1 14	16	$1\frac{3}{8}$	22 0 0
6	1	6 0 0	17	$1\frac{1}{2}$	21 0 0
7	1	7 0 0	17	$1\frac{3}{8}$	23 1 14
8	1	8 0 0	18	$1\frac{1}{2}$	22 2 0
9	1	9 0 0	18	$1\frac{3}{8}$	24 3 0
9	$1\frac{1}{8}$	10 0 0	19	$1\frac{1}{2}$	23 3 0
10	1	10 0 0	19	$1\frac{3}{8}$	26 0 14
10	$1\frac{1}{8}$	11 1 0	20	$1\frac{1}{2}$	25 0 0
11	1	11 0 0	20	$1\frac{3}{8}$	30 0 0
11	$1\frac{1}{8}$	12 1 14	21	$1\frac{1}{2}$	26 1 0
12	$1\frac{1}{8}$	13 2 0	21	$1\frac{3}{8}$	31 2 0
12	$1\frac{1}{2}$	15 0 0	22	$1\frac{1}{2}$	27 2 0
13	$1\frac{1}{8}$	14 2 14	22	$1\frac{3}{8}$	33 0 0
13	$1\frac{1}{2}$	16 1 0	23	$1\frac{1}{2}$	28 0 0
14	$1\frac{1}{8}$	15 3 0	23	$1\frac{3}{8}$	34 2 0
14	$1\frac{1}{2}$	17 2 0	24	$1\frac{1}{2}$	30 0 0
15	$1\frac{1}{8}$	16 3 14	24	$1\frac{3}{8}$	36 0 0

TABLE VIII.
PIPE FLANGES AND BENDS.

Diameter of Pipe.	Pipes.						Bends.	
	Thickness of Pipe.	Diameter of Flange.	Thickness of Flange.	Centre of Holes.	Number of Holes.	Diameter of Bolts.	Length.	Radius.
in.	in.	in.	in.	in.	in.	in.	in.	in.
2	$\frac{1}{8}$	6	$\frac{3}{8}$	$4\frac{1}{2}$	4	$\frac{1}{2}$	5	$3\frac{1}{2}$
$2\frac{1}{2}$	$\frac{1}{8}$	7	$\frac{1}{2}$	$5\frac{1}{2}$	4	$\frac{5}{8}$	$5\frac{1}{2}$	$3\frac{3}{4}$
3	$\frac{1}{8}$	$7\frac{1}{2}$	$\frac{1}{2}$	$5\frac{3}{4}$	4	$\frac{5}{8}$	$5\frac{3}{4}$	4
$3\frac{1}{2}$	$\frac{1}{8}$	8	$\frac{1}{2}$	$6\frac{1}{2}$	4	$\frac{5}{8}$	$6\frac{1}{2}$	$4\frac{1}{2}$
4	$\frac{1}{8}$	9	1	7	4	$\frac{3}{4}$	$6\frac{1}{2}$	$4\frac{3}{4}$
5	$\frac{1}{8}$	10	1	8	4	$\frac{3}{4}$	$7\frac{1}{2}$	$5\frac{1}{2}$
6	$\frac{3}{8}$	$11\frac{1}{2}$	$1\frac{1}{8}$	$9\frac{1}{2}$	6	$\frac{3}{4}$	8	$5\frac{3}{4}$
7	$\frac{3}{8}$	13	$1\frac{1}{8}$	$10\frac{3}{4}$	6	$\frac{7}{8}$	9	$6\frac{3}{4}$
8	$\frac{3}{8}$	14	$1\frac{1}{8}$	$11\frac{3}{4}$	6	$\frac{7}{8}$	10	7
9	$\frac{3}{8}$	$14\frac{1}{2}$	$1\frac{1}{8}$	$12\frac{1}{2}$	8	$\frac{3}{4}$	$10\frac{1}{2}$	$7\frac{1}{2}$
10	$\frac{3}{8}$	$15\frac{1}{2}$	$1\frac{3}{8}$	$13\frac{1}{2}$	8	$\frac{3}{4}$	11	8
11	$\frac{3}{8}$	$16\frac{1}{2}$	$1\frac{3}{8}$	$14\frac{1}{2}$	8	$\frac{3}{4}$	12	$8\frac{1}{2}$
12	$\frac{1}{2}$	$18\frac{1}{2}$	$1\frac{1}{2}$	$16\frac{1}{2}$	8	$\frac{1}{2}$	13	9
13	$\frac{1}{2}$	$19\frac{1}{2}$	$1\frac{1}{2}$	$17\frac{1}{2}$	8	$\frac{1}{2}$	$13\frac{1}{2}$	$9\frac{1}{2}$
14	$\frac{1}{2}$	$20\frac{3}{4}$	$1\frac{1}{2}$	$18\frac{1}{2}$	8	$\frac{1}{2}$	14	10
15	1	$22\frac{1}{2}$	$1\frac{1}{2}$	$19\frac{1}{2}$	8	$\frac{1}{2}$	15	$10\frac{1}{2}$
16	1	$23\frac{1}{2}$	$1\frac{3}{4}$	$20\frac{1}{2}$	10	$\frac{7}{8}$	16	11
17	1	$24\frac{1}{2}$	$1\frac{3}{4}$	$21\frac{1}{2}$	10	$\frac{7}{8}$	$16\frac{1}{2}$	$11\frac{1}{2}$
18	$1\frac{1}{8}$	26	$1\frac{7}{8}$	23	10	1	17	12
19	$1\frac{1}{8}$	27	$1\frac{7}{8}$	24	10	1	18	$12\frac{1}{2}$
20	$1\frac{1}{8}$	28	2	25	10	1	19	$13\frac{1}{2}$
21	$1\frac{1}{8}$	29	2	$26\frac{1}{2}$	10	$1\frac{1}{8}$	$19\frac{1}{2}$	14

TABLE IX.

SIZES OF BUCKETS AND CLACKS.

Diameter of Work- ing Barrel.	Buckets and Clacks.				Bucket Shank.		Bucket Hoops.	
	Taper about $\frac{1}{8}$ Inch to 1 Inch.				Size of Bucket Shank.	Size at Joint of Bucket Shank.	Depth of Bucket Hoops.	Thick- ness at Bottom of Bucket Hoops.
	Depth of Shell.		Thick- ness at Top.	Size of Shank Holes.				
	Middle.	Sizes.						
in.	in.	in.	in.	ft.	in.	in.	in.	in.
6	3	3	$\frac{1}{8}$	$2\frac{1}{2} \times \frac{1}{2}$	$2 \times 1\frac{1}{2}$	2	1	$\frac{1}{8}$
8	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{8}$	$3 \times \frac{1}{2}$	$2\frac{1}{2} \times 1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{8}$
10	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{8}$	$3\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times 1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{8}$
12	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{8}$	$3\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times 1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{8}$
14	4	5	$\frac{1}{8}$	$3\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times 2$	$2\frac{1}{2}$	2	$\frac{1}{8}$
16	$4\frac{1}{2}$	6	$\frac{1}{8}$	$4 \times \frac{1}{2}$	$3 \times 2\frac{1}{2}$	3	$2\frac{1}{2}$	$\frac{1}{8}$
18	$4\frac{1}{2}$	$6\frac{1}{2}$	$\frac{1}{8}$	$4 \times \frac{1}{2}$	$3\frac{1}{2} \times 2\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{8}$
20	5	$6\frac{1}{2}$	1	$4\frac{1}{2} \times \frac{1}{2}$	$3\frac{1}{2} \times 2\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{8}$
22	$5\frac{1}{2}$	$7\frac{1}{2}$	$1\frac{1}{8}$	$4\frac{1}{2} \times \frac{1}{2}$	$3\frac{1}{2} \times 3$	$3\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{8}$
24	6	$7\frac{1}{2}$	$1\frac{1}{2}$	5×1	$3\frac{1}{2} \times 3\frac{1}{2}$	$3\frac{1}{2}$	3	$\frac{1}{8}$

Dimensions marked * have two holes below.

TABLE X.

SPEARS AND BUCKET RODS.

Diameter of Pumps.	Spear, Square.	Spear-plates and Bolts.					Bucket Rods.	
		Length.	Breadth.	Thickness in Middle.	Thickness at Ends.	Diameter of Bolts.	Square	Length of U-plates.
in.	in.	ft.	in.	in.	in.	in.	in.	ft.
6	3	6	$2\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$1\frac{1}{2}$	$4\frac{1}{2}$
8	$3\frac{1}{2}$	$6\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$1\frac{1}{2}$	$4\frac{1}{2}$
10	4	7	3	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	2	5
12	$4\frac{1}{2}$	$7\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$2\frac{1}{2}$	$5\frac{1}{2}$
14	5	8	$3\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$2\frac{1}{2}$	$5\frac{1}{2}$
16	$5\frac{1}{2}$	$8\frac{1}{2}$	4	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$2\frac{1}{2}$	6
18	6	9	4	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	3	$6\frac{1}{2}$
20	$6\frac{1}{2}$	9	$4\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	1	$3\frac{1}{2}$	7
22	7	10	$4\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	$1\frac{1}{2}$	$3\frac{1}{2}$	$7\frac{1}{2}$
24	$7\frac{1}{2}$	$10\frac{1}{2}$	$4\frac{1}{2}$	1	$\frac{1}{8}$	$1\frac{1}{2}$	$3\frac{1}{2}$	8

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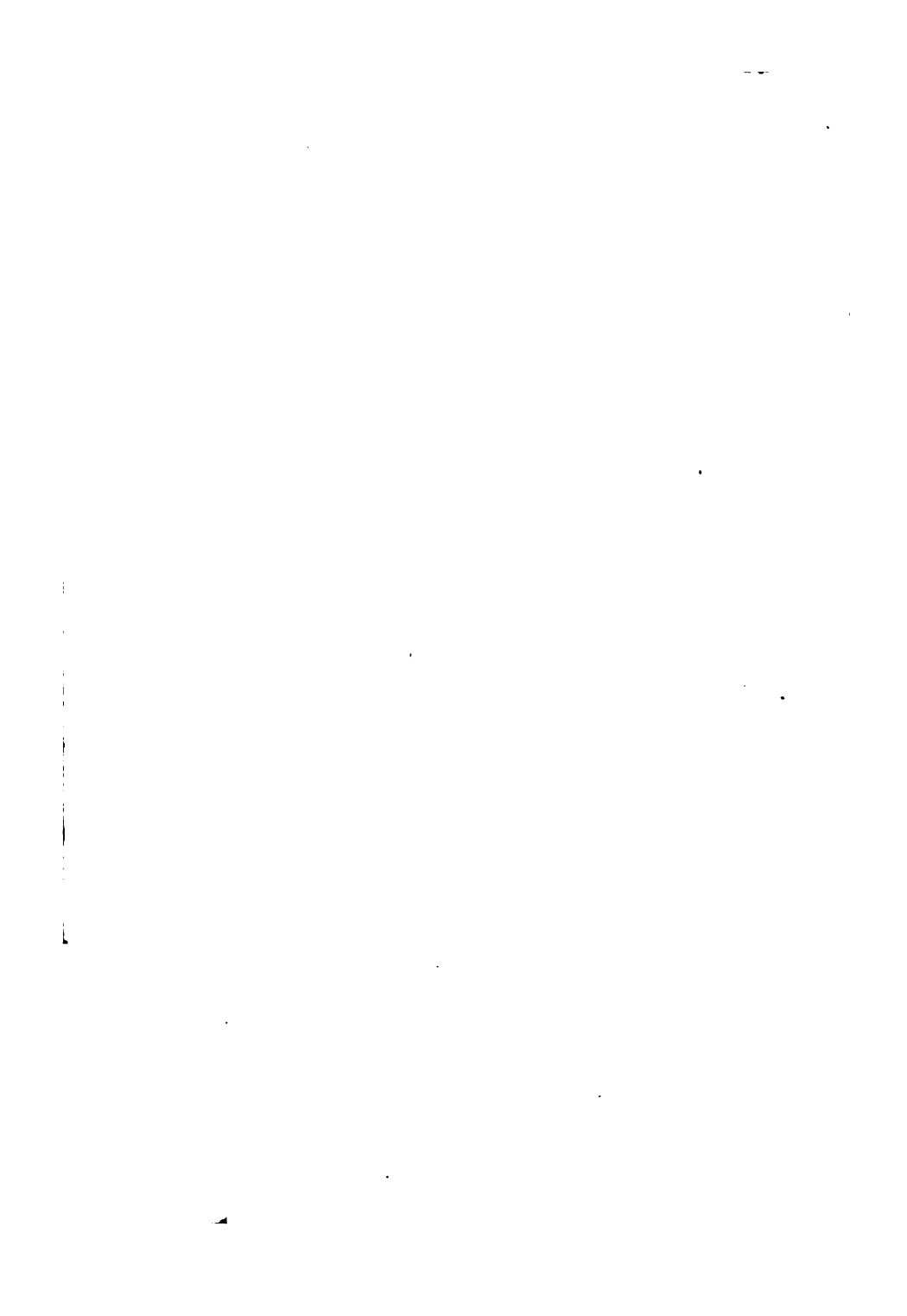
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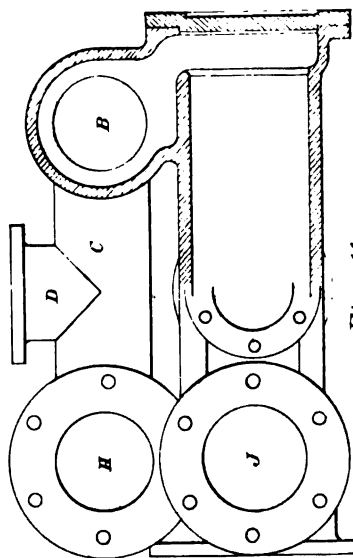
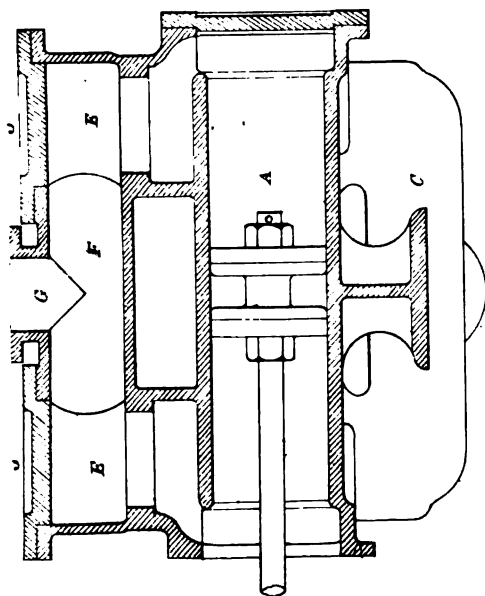
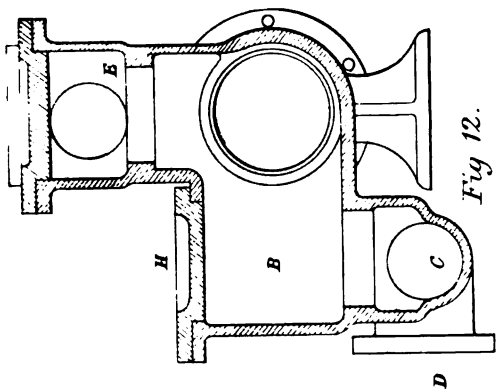
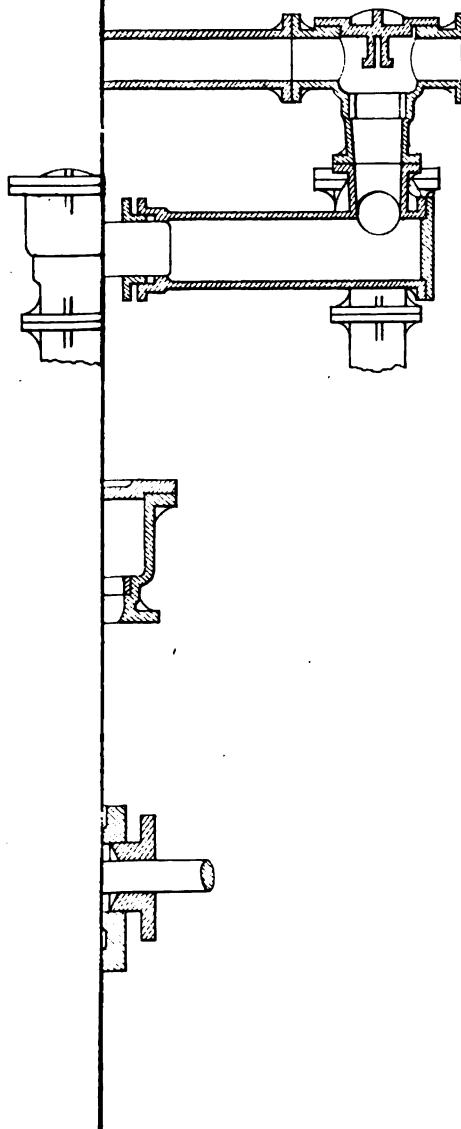


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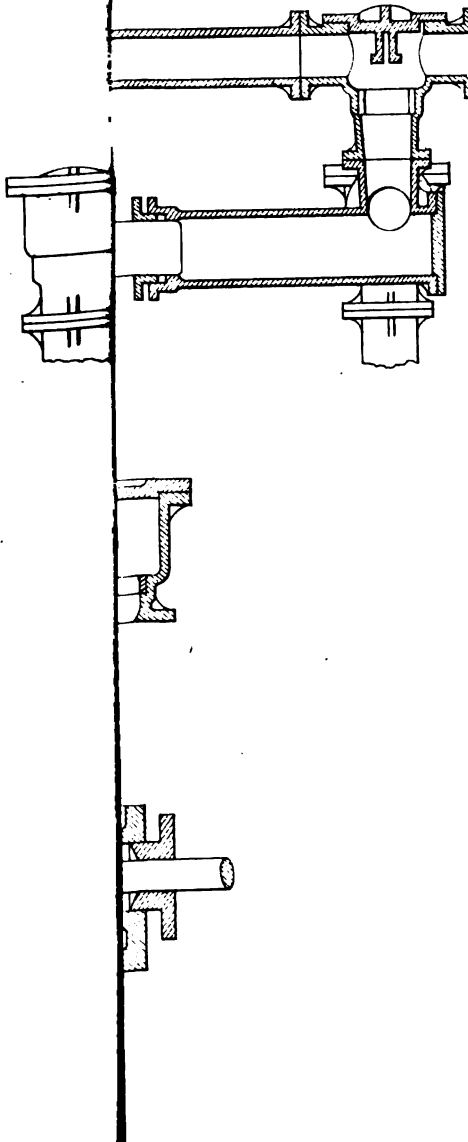


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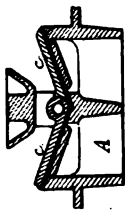


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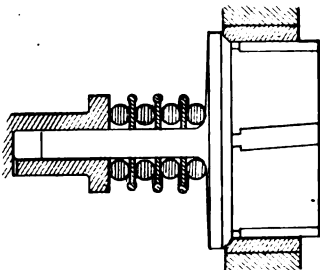


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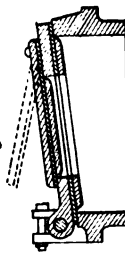


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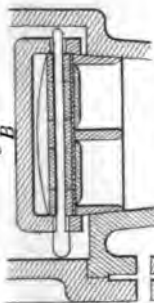


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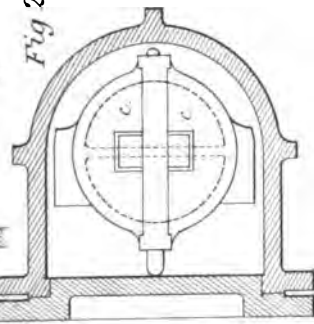


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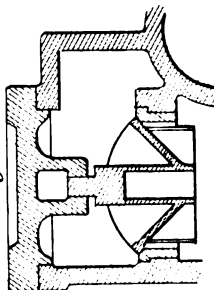


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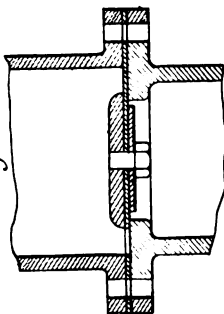


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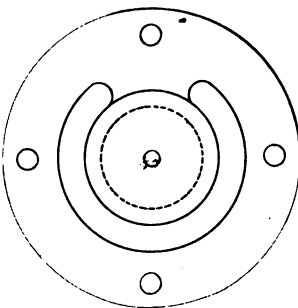
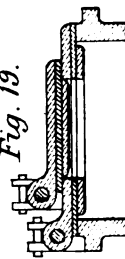


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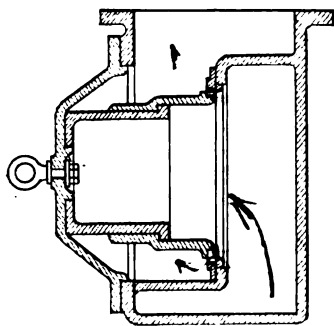


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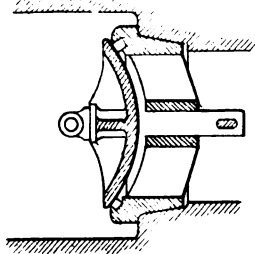


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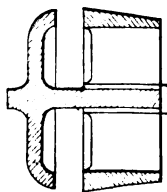


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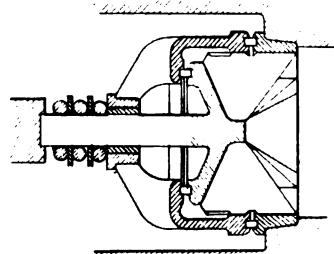


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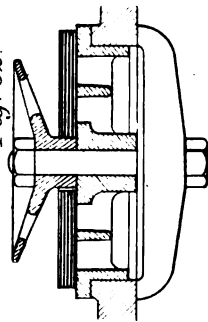


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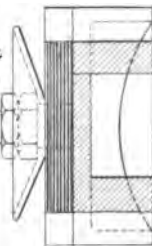




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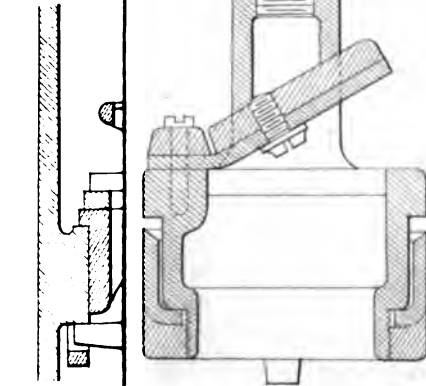
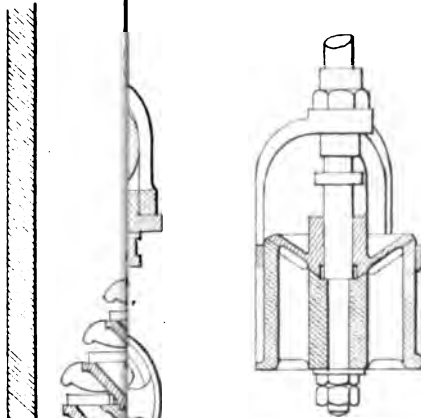


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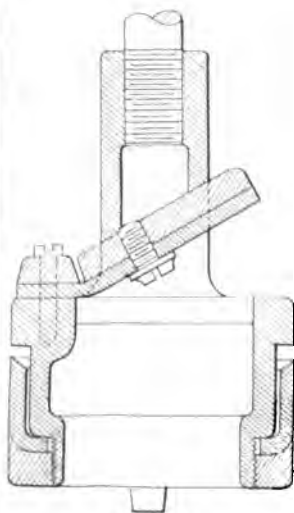
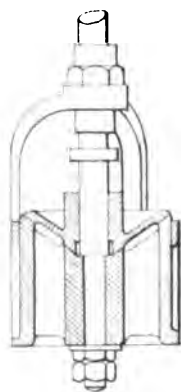
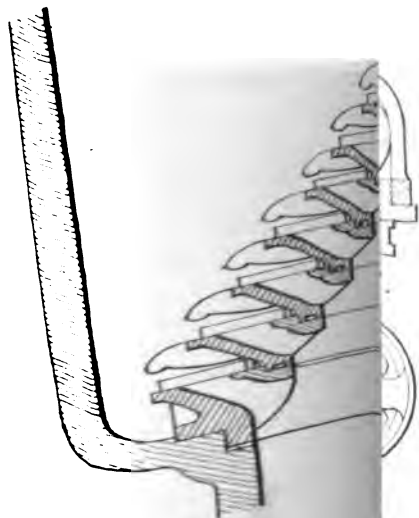


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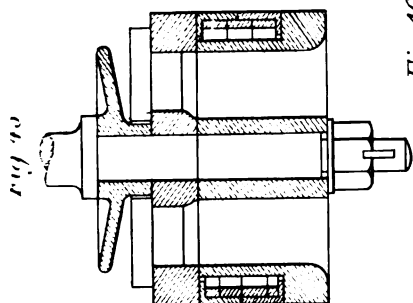


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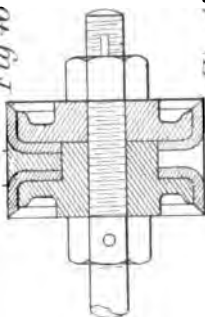


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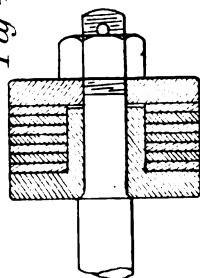


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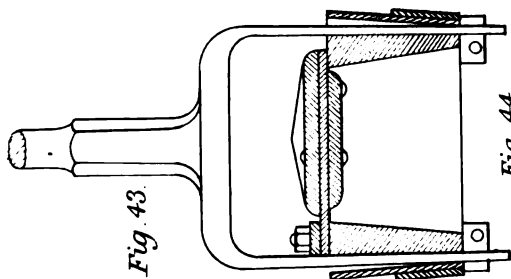


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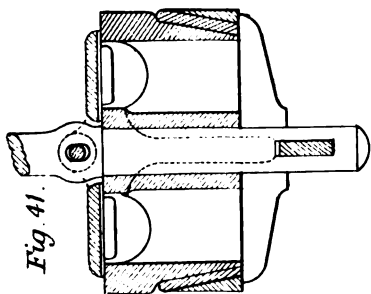
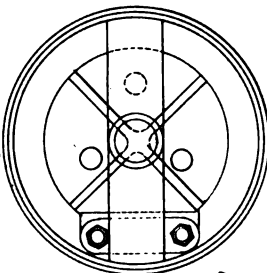


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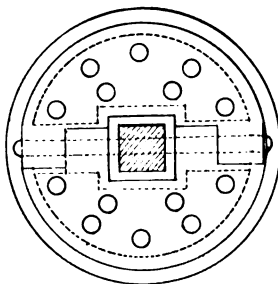




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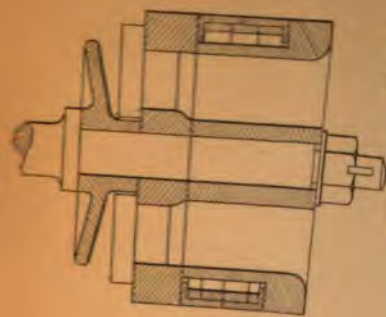


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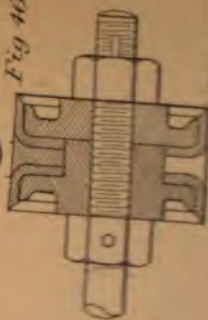


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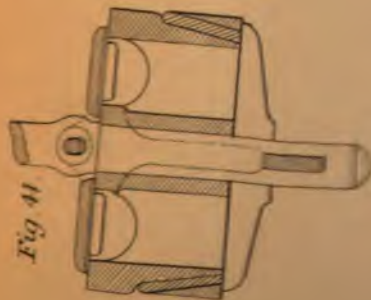


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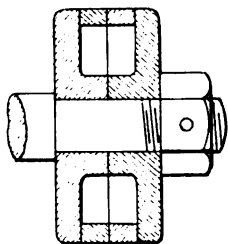


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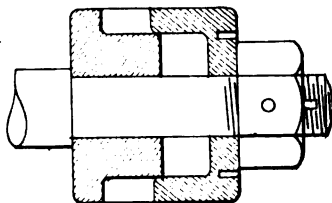


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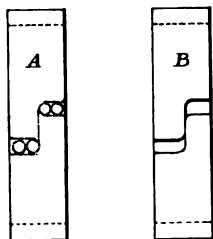


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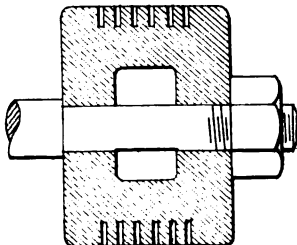


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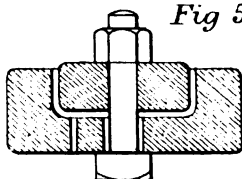
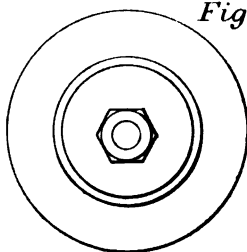


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